3GPP TSG-RAN WG1 Meeting #102-e R1-20xxxxx

e-Meeting, August 17th – 28th, 2020

Agenda Item: 8.4.2

Source: Thales (moderator)

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

Document for: Discussion

# Introduction

This document contains a summary of the contributions under 8.4.2 at TSG-RAN WG1 #102-e. Discussions and clarification on UE capability are summarized in Section 3. Discussions on uplink timing synchronization and uplink frequency synchronization are summarized in Section 4 and Section 5 respectively. Discussion on serving satellite ephemeris is summarized in section 6.

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# Clarification on UE capability

As per Rel-17 NR\_NTN\_solutions WI, UEs are assumed to have GNSS support. MediaTek , CATT observed that GNSS capability working assumption is that UE can determine and pre-compensate timing and frequency offset [16,3]. Thales and InterDigital proposed that for UL time offset compensation, UE calculation of the TA value based on UE location and satellite ephemeris is supported [23, 13, 16]. Further, Ericsson, proposed that NR NTN UE shall be capable of using an acquired GNSS position and satellite ephemeris to calculate pre-compensation of timing and frequency offset at least in RRC idle and RRC inactive mode [8]. Additionally, Ericsson proposed for RAN1 to determine the need for support of GNSS in RRC connected for the purpose of timing and frequency adjustment [8].

On the other hand, CMCC, ZTE, Apple ,CAICT, and Sony want to consider the support of both UEs with and without capability on GNSS-based timing and frequency pre-compensation. ZTE proposed that UE capability to support GNSS and pre-compensation should be defined separately [24].

Finally, LG Electronics preferred to not assume GNSS-based frequency and time pre-compensation at UE side.

The following regarding UE capability were discussed by the different companies:

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| **Companies** | **Comments / Proposals** |
| ZTE | Proposal 2: UE capability to support GNSS and pre-compensation should be defined separately. |
| Thales | Proposal 2. RAN1 to assume that the UE can derive its location based only on its GNSS capabilities. |
| MediaTek , Eutelsat | Observation 1: GNSS capability working assumption is that UE can determine and pre-compensate timing and frequency offset with sufficient accuracy for UL transmission. |
| CATT | Based on WID scope, it is assumed that UE has GNSS capability and can be able to conduct time-frequency compensation based on UE position and ephemeris information. For the UE without pre-compensation capability, it is not focus of Rel-17 WID. |
| Ericsson | UE support for GNSS based time and frequency compensation in RRC idle and inactive, while support in RRC connected is considered as an optional feature:   * Proposal 1: NR NTN UE shall be capable of using an acquired GNSS position and satellite ephemeris to calculate pre-compensation of timing and frequency offset and apply the calculated values accordingly at least in RRC idle and RRC inactive mode. * Proposal 2: RAN1 to determine the need for support of GNSS in RRC connected for the purpose of timing and frequency adjustment.   Proposal 3 RAN1 to determine the need for support of GNSS measurement gaps in RRC connected.  Proposal 4 RAN1 to determine if NR NTN UE should indicate capability support for simultaneous GNSS and NR operation, with or without GNSS measurement gaps. |
| InterDigital, Inc. | Observation 2: All Rel-17 NTN-capable UEs are assumed to have GNSS support and knowledge of satellite location via ephemeris data periodically broadcast SI.  Proposal 1: for UL time offset compensation, UE calculation of the TA value based on UE location and satellite ephemeris is supported (Option-1). |

Potential proposal 1: RAN1 to identify scenarios whether GNSS-equipped UEs cannot perform timing and frequency pre-compensation for uplink synchronization based on their GNSS capabilities

The companies to provide their comments and views in the following table:

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| **Companies** | **Comments and Views** |
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# UL timing synchronization for NTN

For UL timing synchronization the following solutions are identified in the submitted TDOCs :

* **Option 1**: Autonomous acquisition of the TA at UE before PRACH transmission based on:
  + Its GNSS capability used in combination with Network indication of:
    - Serving satellite ephemeris
    - Or time stamp (e.g. ReferenceTimeInfo-r16)
  + And a possible common TA indication
* **Option 2**: Acquisition of the TA at UE before PRACH transmission based on:
  + Common TA indication

**Option 1** will not require a new design of the PRACH assuming that autonomous acquisition can be performed with sufficient accuracy. That is the existing PRACH format can be reused in NR NTN. This option assumes that UEs with GNSS use their GNSS capability to determine and pre-compensate timing for uplink synchronization.

On the other hand, **option 2** would require a new RACH design for differential TA and Doppler exceeding capability of rel-15 RACH design. Option 2 implies that UE GNSS capabilities are not used for the TA pre-compensation.

**Option 1** seems to be the preferred option by the majority companies.

LG Electronics proposed to consider option 2 only.

CMCC, ZTE , Apple, CAICT, and Sony want to consider both options.

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| **Companies** | **Comments / Proposals** |
| CMCC | Proposal 1: Both Option 1 (Autonomous acquisition of the TA at UE) and Option 2 (Timing advanced adjustment based on network indication) should be discussed and supported. |
| ZTE | Proposal 5: For UL synchronization, both BS-dominated and UE-dominated mechanism can be considered. |
| Apple | Proposal 1: For UEs with autonomous TA acquisition, the full TA is applied for PRACH transmission. For UEs with network indicated TA, the common TA is applied for PRACH transmission. |
| CAICT | Proposal5: It is suggested to adopt Option2 without enlarging the UE’s transmission delay, otherwise it is suggested UE can report its TA to the network in Option1. |
| LG Electronics | Proposal 1. For the timing advance (TA) in the initial access and the subsequent TA maintenance, the option that the gNB can provide both common TA and UE specific differential TA (i.e., Option 2) is preferred over the autonomous acquisition of the TA at UE side (i.e., Option 1). |
| Sony | Proposal 1: Timing advance adjustment based on network indication (option 2) should be supported. |

Potential proposal 2: RAN1 to further discuss options for acquisition of TA by the UE:

* **Option 1: Autonomous acquisition of the TA at UE before PRACH transmission based on:**
  + **Its GNSS capability used in combination with Network indication of:**
    - **Serving satellite ephemeris**
    - **Or time stamp (e.g. ReferenceTimeInfo-r16)**
  + **And a possible common TA indication**
* **Option 2: Acquisition of the TA at UE before PRACH transmission based on:**
  + **Common TA indication**

The companies to provide their comments and views in the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
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## Initial acquisition of TA before PRACH preamble transmission

### Autonomous acquisition based on UE GNSS capabilities

With **option 1**, many questions remain: What part of the TA the UE need to pre-compensate? Full TA? Partial TA? Which delay should be compensated by the network transparently to the UEs? Does the gNB still needs to indicate the common TA to the UE?

The answers to those questions depend on the position of the reference point for UE TA calculation. There are different views and proposals from different companies regarding this reference point as it will be discussed in the following section.

#### Reference point for autonomous acquisition of the TA at UE:

The reference point or RP is defined as the point w.r.t. which the TA is computed at UE side. As a consequence, it is the only point where the timing alignment of UL and DL frames can be observed.

The RTD experienced between the gNB and the RP shall be handheld by the network/gNB and is masked to the UE from a synchronization point of view.

The companies have identified the following 3 options regarding the RP definition :

**RP OPTION 1:**

The RP is located at the gNB. The initial TA acquisition (before PRACH transmission) is computed as the sum of two distinct contributions :

* The UE specific TA which is autonomously acquired by the UE based on its GNSS capabilities and additional network indications (e.g. satellite ephemeris or time stamp). It corresponds to the service link RTD.
* The Common TA which is indicated by the network. It corresponds to the RTD experienced between the RP and the satellite.



Figure 1 RP OPTION 1

**RP OPTION 2:**

The RP is located at the satellite. The initial TA acquisition (before PRACH transmission) is computed as the sum of two distinct contributions :

* The UE specific TA which is autonomously acquired by the UE based on its GNSS capabilities and additional network indications (e.g. satellite ephemeris or time stamp). It corresponds to the service link RTD.
* In this case, the Common TA which corresponds to the RTD experienced between the RP and the satellite is always equal to zero. The common TA indication may not be needed.



Figure 2 RP OPTION 2

**RP OPTION 3**

The RP localization is not specified and left to the implementation. The initial TA acquisition (before PRACH transmission) is computed as the sum of two distinct contributions :

* The UE specific TA which is autonomously acquired by the UE based on its GNSS capabilities and additional network indications (e.g. satellite ephemeris or time stamp). It corresponds to the service link RTD.
* The Common TA which is indicated by the network. It corresponds to the RTD experienced between the RP and the satellite. The common TA can be either positive or negative. As a consequence, the RP can be located either on the feeder link or the service link.



Figure 3 RP OPTION 3

A comparison between these three different options is summarized in the following table:

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| --- | --- |
| **Reference point for timing synchronization** | **Comments** |
| RP Option 1 | * The UE determines autonomously the TA corresponding to the service link RTD * To determine the full TA the network needs to broadcast the common TA * UE can derive/obtain the gateway location |
| RP Option 2 | * The UE determines autonomously the full TA corresponding to the service link RTD * Broadcast common TA may not be needed * But, RTD experienced between the gNB and the RP shall be handheld by the network/gNB. Additional complexities for the gNB to manage the timing offset between the DL and UL frame timing which will shift over time * UE cannot obtain the gateway location |
| RP Option 3 | * The UE determines autonomously the partial TA corresponding to the service link RTD * gNB needs to broadcast the common TA * The delay compensated by network can be a constant value: the timing offset between the DL and UL frame timing is fixed * UE cannot obtain the gateway location |

Potential Proposal 3 : RAN1 to further discuss the following options for initial TA acquisition :

* RP Option 1 : RP is located at the gNB. Common TA indication shall be introduced.
* RP Option 2 : RP is located at the satellite. Common TA indication may be avoided.
* RP Option 3 : RP localization is left to the implementation. Common TA indication shall be introduced to support all the foreseen deployment scenarios.

Note: The Common TA which is indicated by the network corresponds to the RTD experienced between the RP and the satellite.

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

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| **Companies** | **Comments and views** |
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The following proposals and observations regarding the RP were discussed by different companies:

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| **Companies** | **Comments / Proposals** |
| Ericsson | Proposal 9 The serving satellite should serve as the point of time and frequency reference in an NTN |
| Thales | Proposal 6: Consider the satellite as the reference from a timing and frequency synchronization point of view  Proposal 7: Broadcast the common delay between the gNB and the satellite in the NTN SIB |
| Qualcomm Incorporated | Proposal 1: In NTN, UE targets UL transmit time and frequency at the arrival of its connected satellite, i.e., UE does not autonomously compensate time delay and frequency errors introduced by the satellite transponder and the feeder link. |
| MediaTek | Proposal 7: Further discuss the following two options for Autonomous acquisition of the TA at UE:  -UE uses the satellite time as the reference point for timing synchronization  -UE uses the Gateway/gNB time as the reference point for timing synchronization |
| CAICT | Proposal1: It is suggested to let the network measure the timing offset between the DL and UL frame introduced by the feeder link and indicate it to the UE for TA refinement in case of satellite with transparent payload. |
| CATT | Considering the implementation flexibility, reference point can be set in the satellite or on the earth. If reference point is in the satellite, UE is only required to compensate the service link TA, and gNB compensates the feeder link TA.  Observation 3: Compensation of full TA would cause additional signaling overhead, and complicate UE behaviors.  Proposal 3: UE only needs to compensate for the UE-specific differential TA. |
| CMCC | Proposal 4: W.r.t. Option 1 (Autonomous acquisition of the TA at UE) in transparent payload case, Alt 2a (i.e., UE specific differential TA compensation at UE side, where the reference point is co-located with the satellite) can be considered for FDD only mode, since it can minimum network indication overhead. |
| Panasonic | Significant DL-UL time difference might be observed at gNB depending on NTN scenarios. Cell specific TA offset (or common TA) via SIB would be useful to reduce the DL-UL time difference to a manageable level at gNB  Proposal 2: Cell specific TA offset should be supported in order to allow compensation of feeder link delay to some extent. |
| Xiaomi | Proposal 2: In order to reduce impacts to UEs, common TA compensated by network is preferred.  Proposal 3: The RTD of feeder link should be transparent to UEs.  The common TA coming from service link and feeder link should be compensated by network, and is transparent to UEs |
| Nokia | Observation 6: If the gNB is set to pre-compensate the Feeder Link delay, the UL timing will shift over time relative to the DL reference derived from the gNB.  Observation 7: If the gNB is set to pre-compensate the Feeder Link delay, there will be an impact in the procedure of autonomous adjustment of TA by the UEs in connected mode |
| ZTE | Proposal 4: Full TA compensation at UE side to ensure the DL/UL frame boundary alignment at BS side should be considered as the baseline assumption. |
| Huawei | Observation 5: The time-variant timing offset between the DL and UL frame timing may introduce much more complexities to the gNB.  Proposal 3: The delay compensated by the network can be a constant value instead of the feeder link RTD, considering the implementation complexity at gNB side.  Proposal 4: For GNSS UE, introduce common TA parameter(s) to derive a feasible TA. |

#### UE specific TA definition

With option 1, the UE needs to acquire autonomously its UE specific TA. Most companies proposed that this UE specific TA corresponds to the service link RTD.

Potential Proposal 4 : In case of Autonomous acquisition of the TA (i.e. Option 1), the UE specific TA shall correspond to the RTD experienced on the service link.

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

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| **Companies** | **Comments and views** |
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#### Autonomous TA acquisition based on GNSS and serving satellite ephemeris

Based on its GNSS capability and using the broadcasted ephemeris data, the UE can calculate its UE specific TA by estimating the RTD experienced on its service link. This is proposed by different companies:

|  |  |
| --- | --- |
| **Companies** | **Comments / Proposals** |
| Thales  MediaTek , Eutelsat | The UE pre-compensates the service link delay on the UL: Knowing its own position using its GNSS capability and knowing the position of the satellite as broadcast on NTN SIB, the UE can determine the propagation distance between itself and the satellite and the corresponding propagation delay. |
| Huawei | For UE with GNSS, the RTD of service link can be calculated with its location and satellite ephemeris.  How much TA a UE needs to apply in NTN scenarios can be configured by the network to meet the requirements of different deployment strategies  Observation 6: For GNSS UE, common TA related parameter(s) is needed regardless of whether gNB compensates for part of RTD.  Proposal 3: The delay compensated by the network can be a constant value instead of the feeder link RTD, considering the implementation complexity at gNB side.  Proposal 4: For GNSS UE, introduce common TA parameter(s) to derive a feasible TA. |
| ETRI | Proposal 1: At least the RTT of service link can be reflected in the UL transmission timing. The reflected value for service link is a value estimated by UE or a common value indicated by gNB. If the estimated value is used, a procedure for gNB to acquire the RTT of service link can be required. |
| Qualcomm Incorporated | Proposal 1: In NTN, UE targets UL transmit time and frequency at the arrival of its connected satellite, i.e., UE does not autonomously compensate time delay and frequency errors introduced by the satellite transponder and the feeder link. |
| Panasonic | GNSS capable UE can estimate the propagation delay for service link from the UE location and the satellite ephemeris  Proposal 1: GNSS capable UE should utilize UE autonomous TA based on UE location and satellite ephemeris. |
| CATT | Considering the implementation flexibility, reference point can be set in the satellite or on the earth. If reference point is in the satellite, UE is only required to compensate the service link TA, and gNB compensates the feeder link TA.  Proposal 3: UE only needs to compensate for the UE-specific differential TA. |
| InterDigital, Inc. | Observation 3: All Rel-17 NTN-capable UEs can determine UE-specific TA value with location information of UE and satellite, and additional information regarding the feeder link delay.  Proposal 1: for UL time offset compensation, UE calculation of the TA value based on UE location and satellite ephemeris is supported (Option-1). |
| LG Electronics | Observation 1. Regarding to Option 1, the approach that the only UE specific differential TA should be compensated at the UE side is preferred over the approach that the full TA should be compensated at the UE side.  Proposal 2. If Option 1 is down-selected, the approach that the only UE specific differential TA should be compensated at the UE side is preferred. |
| ZTE | As one alternative, information on location, mobility situation of network with certain confidence level are needed to enable the calculation on the UE-specific value at UE side.  e.g., satellite ephemeris once the reference point-1 … or trajectory information in case that reference point-2 is assumed |

Potential proposal 5: NR NTN UE shall be capable of using an acquired GNSS position and satellite ephemeris to autonomously acquire its TA, at least in RRC idle and RRC inactive mode.

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

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| **Companies** | **Comments and views** |
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#### Autonomous TA acquisition based on time stamps broadcast

Another alternative for UL time synchronization based on time stamps broadcast (e.g. NR Rel-16 ReferenceTimeInfo-r16) is proposed by Nokia, Intel [5] and ZTE:

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| --- | --- |
| **Companies** | **Comments / Proposals** |
| Nokia | Proposal 3: RAN1 should consider the solution of utilizing gNB broadcast of ReferenceTimeInfo-r16 in SIB9 and UE GNSS capability as the main mechanism for obtaining time related information for the NTN system.  Proposal 4: Prior to any RA attempt, a GNSS capable UE should have read SIB9. |
| Intel Corporation | Proposal 2: At least the following options can be considered for pre-compensation of time shift and frequency offset for UL transmission   * Opt. 1: Time shift and frequency offset values are determined using the UE position and velocity based on GNSS, satellite position and velocity based on broadcast information * Opt. 2: Time shift and frequency offset values are determined using the accurate UTC time at the UE, absolute UL carrier frequency based on GNSS, accurate UTC time at the gNB based on broadcast information and DL carrier frequency at the UE based on DL reference signals |
| ZTE | * As another alternative, indication of other information, i.e., time stamps (from reference point 0 where the DL data is transmitted) can also be considered. In this way, the acquisition of TA and frequency values (as the combination of UE-specific and Common) can be enabled via calculation at UE side based on absolute propagation time and its variation rate * But the ideal synchronization of clock between BS and UE should be always assumed |

Potential Proposal 6: RAN1 to further discuss if autonomous TA acquisition based on GNSS and time stamp broadcast (e.g. ReferenceTimeInfo-r16) shall be supported in Release 17 NTN

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

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| **Companies** | **Comments and views** |
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#### Discussion on common TA and delay on the feeder link

The way the feeder link delay will be handled is conditional on the RP position. In the case where the RP option 1 is assumed, the RTD on the feeder link is compensated by the UE based on the common TA indication. In case RP option 2 is assumed, the RTD on the feeder link is transparent to the UE and handled at gNB side. In case of RP option 3, the RTD on the feeder link is partially compensated by the UE based on the common TA indication.

Some companies initiate the discussion on what parameters need to be signalled to the UE to indicate this common TA. Thales proposed to broadcast the common delay between the gNB and the satellite in the NTN SIB [23]. MediaTek proposed in [11] that options for mitigation of delay drift over feeder link are for further study. According to Huawei, for GNSS UE, common TA related parameter(s) is needed regardless of whether gNB compensates for part of RTD. CMCC and Asia Pacific Telecom proposed to broadcast the location of the gNB/GW [4].

Proposals and observations made by different companies are gathered in the following table:

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| --- | --- |
| **Companies** | **Comments / Proposals** |
| Thales | Proposal 7: Broadcast the common delay between the gNB and the satellite in the NTN SIB |
| MediaTek [11] | Proposal 4: Options for mitigation of Delay drift over feeder link are for further study  • Feeder link delay drift compensation error requirement  • gNB indication of feeder link delay drift  • Gateway/gNB compensation of feeder link delay drift |
| Huawei | Observation 6: For GNSS UE, common TA related parameter(s) is needed regardless of whether gNB compensates for part of RTD.  Proposal 4: For GNSS UE, introduce common TA parameter(s) to derive a feasible TA. |
| Panasonic | Cell specific TA offset (or common TA) via SIB would be useful to reduce the DL-UL time difference to a manageable level at gNB  Proposal 2: Cell specific TA offset should be supported in order to allow compensation of feeder link delay to some extent. |
| CMCC | Proposal 3: W.r.t. Option 1 (Autonomous acquisition of the TA at UE) in transparent payload case, Alt 1 (i.e., full TA compensation at UE side) with additional network indication of gateway related information (e.g., gateway’s location or the distance between the satellite and the gateway) is preferred for both TDD and FDD duplex mode, since it can keep DL and UL frame timing aligned at gNB side to simplify gNB’s design.  Proposal 5: W.r.t. autonomous acquisition of the TA at UE, broadcasting of the [coarse] location of gNB via system information is suggested to support ATG scenario. |
| Asia Pacific Telecom | Proposal 3 For autonomous acquisition of the TA at UE with UE known location and satellite ephemeris, at least signal ephemeris along with gateway position to the UE shall be supported in Rel-17 NTN. |

Potential Proposal 7: In case option 1 is assumed for UL timing synchronization, RAN1 to further discuss how to indicate the common TA to the UE:

* **gNB indication of common TA**
* **gNB indication of common TA drift**
* **gNB/ NTN GW position**

**Note: The Common TA is indicated by the network. It corresponds to the RTD experienced between the RP and the satellite.**

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

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| **Companies** | **Comments and views** |
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### Timing advanced adjustment based on network indication (option 2)

As already mentioned, CMCC, OPPO, Samsung, Sony, Lenovo, Motorola Mobility, Apple, CAICT and ZTE want to consider option (2). With this option the gNB needs to broadcast the common TA to all UEs within the coverage of same satellite beam/cell. This option would require a new RACH design for differential TA and Doppler exceeding capability of rel-15 RACH design.

Option 2 implies that GNSS is not used for the TA pre-compensation.

There are quite different views regarding the number of reference points to be considered for Common TA calculation as depicted in the following table:

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| **Companies** | **Comments / Proposals** |
| CMCC | Proposal 6: With regards to the option 2, only the single reference point per beam for common TA calculation is supported, the reference point for common TA calculation is the beam/cell center, and the common TA can be periodically broadcast to UE.  Proposal 7: For the extension of the TA value range, the negative TA value is supported. |
| OPPO | Proposal 1: Consider the gNB signaling CTA as a baseline, further discuss the concrete design of CTA signaling.  Proposal 4: for gNB signaling CTA, TA command in RAR should cover the remaining TA delta. |
| Samsung | Observation 1: Two approaches for TA compensation, i.e., autonomous compensation at the UE and gNB indication, are feasible  Proposal 1: Range of UL TA should be increased to accommodate large propagation delay.  Proposal 2: Multiple reference points and common TA values should be considered for extremely large cells. |
| Sony | Proposal 1: Timing advance adjustment based on network indication (option 2) should be supported.  Observation 1: All UEs compensating at least the common TA will minimize standardization effort on new long RACH preambles.  Proposal 2: RAN1 should support TA compensation with configuration of the common TA.  Proposal 4: RAN1 should adopt only one reference point for common TA calculation.  Observation 5: The maximum UE-specific differential TA in NTN will be larger than the TA in terrestrial networks and so require more bits for TA in the RAR.  Proposal 5: RAN1 should agree the maximum functional altitude of an NTN UE and use this as the altitude of the reference point for calculating the common TA.  Proposal 6: RAN1 should consider the impact of feeder link delay changes on the common TA. |
| Lenovo, Motorola Mobility | For calculation of common TA in the options (1) and (2) (discussed in §3) , single reference point per beam is considered as the baseline. Whether and how to support the multiple reference points can be further discussed in the normative work  Proposal 1: Common TA is indicated per beam.  Proposal 2: Common TA value is implicitly indicated by SSB/CSI-RS resource index.  Proposal 3: When there is contradiction among common TA value for uplink transmission, a default common TA value or a latest common TA value can be used.  Proposal 5: Single reference point is baseline. Multiple reference points can be FFS. |
| ZTE | BS-dominated mechanism: In this way, except for broadcasting of common TA per beam, due to the large frequency and timing offset within the coverage of one beam, the enhancement on the existing PRACH preamble/format is still needed |
| Apple | Proposal 3: Multiple reference points per beam are not supported for common TA calculation.  Proposal 4: The TA command in RAR needs to be enhanced to indicate larger TA values. |
| CAICT | Proposal2: Applying the common TA at the network side is preferred.  Proposal3: In case of multiple common TAs due to more than one reference points, it is suggested to build an association relationship between the common TA and SSB indexes or PRACH resources, such that the network or UEs can apply the common TA according to associated the SSB indexes or PRACH resources.  Proposal4: It is suggested to extend the TA indication value range in RAR by using more bits for TA indication in RAR, or implicitly by some modifications in the RAR detection procedure. |

As already proposed in Potential Proposal 1, the companies are encouraged to first identify the scenarios whether GNSS-equipped UEs cannot perform timing and frequency pre-compensation for uplink synchronization before discussing the solutions to support these scenarios

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

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| **Companies** | **Comments and views** |
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## UL Time synchronization requirements

According to Nokia, Thales and MediaTek, for UL timing synchronization, the timing error after pre-compensating the delay before the initial RACH preamble transmission needs to fall within half the Preamble Cyclic Prefix (CP) [16, 23]. Further, MediaTek provided the requirements related to UE autonomous acquisition of the Timing Advance in terms of satellite position accuracy.

The proposals regarding UL Time synchronization requirements are listed in the following table:

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| --- | --- |
| **Companies** | **Comments / Proposals** |
| OPPO | Observation 3: minimum estimation accuracy is needed for UE autonomous TA estimation.  Proposal 2: Further discuss the estimation accuracy requirement for UE autonomous TA estimation. |
| ZTE | Proposal 6: Evaluation of accuracy for pre-compensation at UE side should be conducted. |
| Huawei [x] | Proposal 5: RAN1 is suggested to study how to address the ISI issue due to ephemeris error |
| MediaTek , Eutelsat | Proposal 1: The maximum error for UE pre-compensation of satellite delay before transmitting RACH preamble has to be within ±CP/4 of RACH preamble format. In term of satellite position accuracy (ΔU) this corresponds to ±CP/4 c:   * For FR1, the minimum satellite position accuracy requirement to support NR RACH preamble format 0, 1, 2, and 3 is ∆U<±7250 m. * For FR2, the minimum satellite position accuracy requirement to support NR RACH preamble format C0 and C1 with sub carrier spacing up to 120 kHz is ∆U<±378 m. |
| Thales | Proposal 8. The UE shall be able to autonomously acquire its TA with an accuracy better than half the CP duration of the selected PRACH format. |
| Nokia | Proposal 2: RAN 1 to evaluate the feasibility and error-modelling of GNSS-based delay calculation for time synchronization purposes.  Observation 11: The time accuracy required for the initial synchronization estimation has to follow within the cyclic prefix of the random access preamble  Proposal 5: RAN 1 to discuss limits for initial time synchronization estimation accuracy |

Regarding the GNSS position accuracy in the device: Thales proposed that the UE location knowledge shall be considered available at UE side at any given time with acceptable accuracy [23]. It is considered by MedaTek as very accurate,in the order of ±3 m. Further, it has been observed that NTN use cases are characterized by outdoor coverage, where UE GNSS-based position should be always available [16].

Additionally, for Ericsson, a GNSS position acquired by an NR NTN UE should be associated with a timer, after which expiration the position is deemed no longer useful.

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| **Companies** | **Comments / Proposals** |
| Thales | Proposal 3. From RAN1 perspective, the UE location knowledge shall be considered available at UE side at any given time with acceptable accuracy. |
| MediaTek , Eutelsat | The GNSS position accuracy in the device is very accurate. The GNSS position accuracy is in the order of ±3 m. NTN use cases are targeted at outdoor coverage, where UE GNSS-based position should be always available in typical NTN coverage scenarios. |
| Ericsson | Proposal 5 A GNSS position acquired by an NR NTN UE should be associated with a timer, after which expiration the position is deemed no longer useful.  Proposal 6 RAN1 to determine the relevance of the case of NTN coverage but no GNSS coverage. |

**Potential Proposal 8: RAN1 to further discuss the requirements related to UL time synchronization.**

**Potential Proposal 9: RAN1 to further discuss the implication of UL timing alignment requirements on the expected accuracy of the satellite and UE positions knowledge at UE side.**

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

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| **Companies** | **Comments and views** |
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## TA uncertainty handling

During the first acquisition of its UE-specific TA, the UE can either underestimate or overestimate the TA. Thales and MediaTek proposed that an offset TA\_offset = CP/2 of PRACH preamble can be applied by all the UEs on top of their autonomous TA initial acquisition [23]. Whereas Ericsson proposed to introduce a parameter whose value could be made configurable to account for the estimation uncertainty.

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| **Companies** | **Comments / Proposals** |
| Ericsson | Proposal 10 The UE should apply a TA at PRACH transmission comprising the estimated RTT and the maximum estimation uncertainty.  Proposal 11: The UE applies TA equal to , where is UE’s estimate of TA, depends on band and LTE/NR coexistence, and is a configurable parameter used as a margin to handle the UE’s estimation uncertainty. |
| MediaTek , Eutelsat | Proposal 5: for UE with Autonomous acquisition of the TA, UE shall use TA\_offset of half the cyclic prefix of PRACH preamble when applying the TA pre-compensation.  Observation 4: Release-15 maximum initial timing range is sufficient assuming UE pre-compensate the delay at least within half of cyclic prefix of PRACH preamble.  Observation 5: The Release-15 initial Timing Advance Command range is sufficient assuming idle UE determine autonomously the full TA. |
| Thales | Proposal 9: The UE shall apply a TA offset on top of its first TA acquisition. This offset shall be equal to half the CP duration of the PRACH format configured in the cell.  Observation: In this condition, the residual error committed on the TA first acquisition is by definition a positive delay. This residual error should be indicated by the gNB using the RAR field dedicated to TA |

**Potential Proposal** **10: RAN1 to discuss whether it is necessary to introduce an offset/margin to be added by the UE to its self-calculated TA in order to account for the TA estimation uncertainty**

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

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| **Companies** | **Comments and views** |
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## TA command in RAR

The range of the Timing Advance (TA) command used in case of random access response currently specified does not cover the round trip times experienced in NTN. Samsung proposed that it should be increased to accommodate large propagation delay in case of initial TA acquisition without GNSS. But, according to Ericsson, Thales and MediaTek , there is no need to extend the Release-15 initial Timing Advance Command with the assumption that UE acquires autonomously its TA based on its GNSS [16,23].

The proposals and observations about the TA command in RAR are summarized in the following table:

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| **Companies** | **Comments / Proposals** |
| MediaTek , Eutelsat | Observation 4: Release-15 maximum initial timing range is sufficient assuming UE pre-compensate the delay at least within half of cyclic prefix of PRACH preamble.  Observation 5: The Release-15 initial Timing Advance Command range is sufficient assuming idle UE determine autonomously the full TA. |
| Ericsson | Observation 7 If the self-calculated TA includes a margin for maximum TA estimation error, unipolar TA command in Msg2 is sufficient, i.e., bipolar TA command is not needed in Msg2. |
| Apple | Proposal 2: For UEs with autonomous TA acquisition, support additional signaling of TA command from network to UE for TA refinement. |
| OPPO | The UL synchronization becomes UE autonomous handling. Later, in RAR, the gNB can further fine-tune the TA delta as in the legacy system.  Proposal 4: for gNB signaling CTA, TA command in RAR should cover the remaining TA delta.  Proposal 5: for UE autonomous TA estimation, consider to reduce the TA command overhead. |
| Samsung | Proposal 1: Range of UL TA should be increased to accommodate large propagation delay. |

**Potential Proposal 11: With UE autonomous TA acquisition, the initial Timing Advance Command range does not need to be extended**

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

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| **Companies** | **Comments and views** |
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## TA Maintenance procedure (TA update)

The companies listed in the table below proposed both open and closed loop mechanisms for TA adjustment. Autonomous adjustment of the TA before UL transmission by the UE avoids need for frequent TA update due to satellite time drift, which will reduces signaling overhead in connected mode.

Moreover for Ericsson network can fully rely on UE autonomous TA update/maintenance during RRC connected only for UE supporting GNSS based transmit timing compensation. These UEs may rely on measurement gaps to perform GNSS measurement. For UEs not supporting GNSS based transmit timing compensation during RRC connected,the existing mechanism for TA maintenance, based on MAC CE should be used but enhanced by Network indication of timing drift rate.

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| **Companies** | **Comments / Proposals** |
| Ericsson | Proposal 12 UEs supporting RRC Connected GNSS measurements are allowed to autonomously adjust its TA to seamlessly continue its RRC connection after the service link switch from one satellite to another.  Proposal 13: For UEs not supporting autonomous timing compensation, uplink timing needs to rely on TA signaling and network indication of timing drift rate. The format of the network indication is FFS. |
| Thales | Proposal 10. Enable autonomous TA update at UE side.  The existing timing adjustment loop and the proposed autonomous TA update should be implemented and used in support of each other depending on the configuration |
| MediaTek , Eutelsat | Proposal 6: for connected UEs with autonomous acquisition of the TA, the TA is adjusted by the UE to compensate impact of the time drift before UL transmission. |
| Xiaomi | Proposal 4: Open loop and close loop TA compensation at the UE side should be supported. |
| CATT | Observation 1: In LEO scenario, gNB has to frequently send TA commands to the UE if merely based on closed-loop TA adjustment, which will introduce huge signaling overhead.  Observation 2: Open-loop TA compensation is necessary to relieve TA indication burden.  Proposal 2: Both open-loop and close-loop methods should be supported for TA maintenance in UL transmission of NTN. |
| Qualcomm Incorporated | Observation 3: NR closed-loop time control mechanism alone is not sufficient for NTN.  Proposal 3: In NTN, both UE autonomous and closed-loop time control are supported.  Proposal 6: Consider group-common DCI for UL time and frequency control. |

According to Huawei Timing drift rate is needed considering accuracy and timing tracking of feeder link. And the TA value may become outdated when it arrived at the UE in LEO based NTN. Additionally, MediaTek highlighted [16] that timing drift within NTN RTD exceeds the maximum specified transmission timing error. And for Nokia, the maximum delay drift in NTN is several orders of magnitude higher than the maximum compensation allowed for a common UE in NR. Indeed, the maximum delay drift is in the order of ±40 μs/s whereas, the maximum autonomous time aggregate adjustment rate is: every 200 ms. in FR1 and every 200 ms in FR2.

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| **Companies** | **Comments / Proposals** |
| Nokia | Proposal 6: RAN 1 should evaluate enhancements on the maintenance phase of the timing advance and on the autonomous update by the UE. |
| Huawei | Proposal 6: The timing drift rate is indicated by the gNB.  Proposal 7: The network should pre-correct the indicated TA with the drifted parts when sending out the TA update signalling. |
| MediaTek | Observation 7: The connected UE can autonomously adjust the TA to compensate the impact of the timing drift within specified maximum transmission timing error ±Te = ± 0.39 μs corresponding to a position error of ±117 m. |
| Sony | Observation 3: Applying timing drift rate TA compensation can reduce the inter symbol interference.  Proposal 3: RAN1 should support the signalling of TA drift rate information to the UEs in a beam specific manner. |
| ZTE | The traditional TA adjustment mechanism with additional indication of the timing drift value to handle the timing variant phenomenon should also be considered |

Another enhancement proposed by OPPO is to allow DCI to update the TA adjustment. The DCI could be UE-specific or group-common DCI.

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| **Companies** | **Comments / Proposals** |
| OPPO | Proposal 6: Consider using DCI to update the TA for a UE or a group UE |

**Potential Proposal 12: For UEs with autonomous acquisition of the TA, RAN1 to further investigate the following enhancements on the maintenance phase of the timing advance:**

* **Enable autonomous TA update at UE side, taking into account**
  + **Common TA drift**
  + **UE specific TA drift**

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

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| **Companies** | **Comments and views** |
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# UL frequency synchronization for NTN

## Pre-compensation on the common frequency offset for DL

Since it is expected to reuse the same SSB design as per Release 15/16, Doppler shift pre compensation on the DL is needed to help the DL synchronization at UE side . The pre-compensation of the common frequency offset on DL transmission is considered as a baseline assumption by the companies listed in the following table.

According to Thales and MediaTek, to indicate the common Doppler shift value, in case of Earth fixed beam scenario, a Reference Point (RP) shall be defined for each beam [16, 23]. The Doppler shift experienced on the DL service link will be pre-compensated by the gNB w.r.t. this RP. Its position in ECEF coordinates has to be provided in the SIB. Further, another alternative in case of moving beam scenario is to broadcast the beam-specific common Doppler shift value as proposed by MediaTek [16].

Qualcomm proposed as well the support of the signaling of the compensated value if pre-compensation is applied.

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| **Companies** | **Comments / Proposals** |
| ZTE | Proposal 3: Taking the implementation of pre-compensation and post-compensation on the common frequency offset at BS side for DL and UL, respectively, as baseline assumption. |
| Thales | Proposal 1: UE shall assume that the Doppler shift experienced on the DL service may be partially pre-compensated by the gNB  Proposal 4: NTN SIB includes the satellite PV(T) in ECEF coordinates and the RP position in ECEF coordinates if needed |
| MediaTek | Proposal 8: In case the gNB pre-compensate the common Doppler shift on the access link w.r.t. center of the beam, the beam-specific common Doppler shift value is broadcast on the NTN SIB for moving beam.  Proposal 9: In case the gNB pre-compensate the common Doppler shift on the access link w.r.t. center of the beam, the beam-specific ECEF co-ordinates of a fixed Reference Point (RP) corresponding to the beam centre is broadcast on the NTN SIB for earth-fixed beam. |
| Nokia | Proposal 7: The gNB or satellite pre-compensates in the DL a common frequency offset per beam/cell, caused by the Doppler shift from feeder and access link, to minimize the PSS/SSS searching space for the UE. |
| Qualcomm Incorporated | Proposal 2: 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. |
| Asia Pacific Telecom | Proposal 4: The pre/post compensation of Doppler shift by the network shall be supported in Rel-17 NTN. |

**Potential Proposal 13: In case of pre-compensation of common Doppler frequency shift on DL transmission, the following apply:**

* **gNB indicates the beam-specific co-ordinates of a Reference Point (RP) for earth-fixed beams**
* **gNB indicates the beam-specific common Doppler shift value for earth-moving beams**

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

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| **Companies** | **Comments and views** |
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## UL Frequency Synchronization requirements

For Thales, [23] the residual frequency error after autonomous acquisition of the Doppler shift by the UE shall be sufficiently low such that it can be considered included in the tolerated frequency error of 0.1 ppm already captured in TS38.101.

MediaTek proposed to consider the same requirements of 0.1 ppm [16]. In [16] MediaTek observed that to fulfill such requirement, the satellite position accuracy (ΔU) and satellite velocity accuracy accuracy ΔV, should satisfy: and

For Qualcomm Unless satellite location accuracy at UE side can be less than 1 km, UE UL frequency error without network frequency control is non-negligible.

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| **Companies** | **Comments / Proposals** |
| MediaTek , Eutelsat | Observation 3: Autonomous acquisition of the Doppler shift due to satellite movement before release-15 RACH transmission is at least within ±0.02ppm and is included in the total frequency error for UL transmission of ±0.1 ppm.  Proposal 2: The maximum frequency error for UE pre-compensation of Doppler shift due to satellite movement before transmitting RACH preamble is within ±0.02ppm. In term of satellite position accuracy (ΔU) and satellite velocity accuracy ΔV, this corresponds to and |
| Qualcomm Incorporated | Observation 2: Unless satellite location accuracy at UE side can be less than 1 km, UE UL frequency error without network frequency control is non-negligible. |
| Thales | 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 included in the tolerated frequency error of 0.1 ppm already captured in the specification. |
| ZTE | Proposal 6: Evaluation of accuracy for pre-compensation at UE side should be conducted. |
| Ericsson | Proposal 7 NTN UE should have the capability of satellite trajectory calculation based on a provided orbit representation at a reference time. |

**Potential Proposal 14: RAN1 to further discuss the requirements related to UL frequency alignment.**

**Potential Proposal 15: RAN1 to further discuss the implication of UL frequency alignment requirements on the expected accuracy of the satellite position and velocity and the UE position knowledge at UE side**.

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

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| **Companies** | **Comments and views** |
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## UL frequency synchronization

Two options have been identified, for the maintenance of UL frequency synchronization:

-Option 1: Both the estimation and pre-compensation of UE-specific frequency offset are conducted autonomously at the UE side.

-Option 2: The required frequency offset for UL frequency compensation is indicated by the network to the UE. The acquisition on this value can be done at the network side with detection of UL signals, e.g., preamble.

The companies listed in the following table proposed to support only option 1.

According to MediaTek , Huawei, Thales and CATT, with GNSS capability assumption, there is no need for UL frequency compensation indication if the UE pre-compensation of Doppler shift is done with sufficient accuracy [16, 23, 3].

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| **Companies** | **Comments / Proposals** |
| Ericsson | For UE with GNSS:  Proposal 14: The UE should apply a frequency shift at PRACH transmission compensating for the frequency shift observed on the uplink due to the Doppler stemming from the satellite motion. |
| MediaTek , Eutelsat | UE Autonomous Pre-compensation of Doppler  Observation 9: With GNSS capability, there is no need for UL frequency compensation indication if the UE pre-compensation of Doppler shift is done with sufficient accuracy for the transmission of RACH preamble and subsequent transmission of PUSCH and PUCCH. |
| CATT | For the UL frequency compensation, if UE owns location and ephemeris information, the whole UL Doppler shift caused by satellite moving can be calculated at UE side  Observation 4: The benefit of close-loop UL frequency compensation is not clear.  Propose 6: Close-loop doppler shift compensation is not needed. |
| Huawei | Proposal 1: For GNSS UE, UE-specific UL frequency compensation is conducted at the UE side.  Observation 1: For GNSS UE, UE-specific frequency correction signaling can be avoided |
| Qualcomm Incorporated | Proposal 4: In NTN, both UE autonomous and closed-loop frequency control are supported. |
| Samsung | Observation 2: Two approaches for Doppler shift compensation, i.e., autonomous compensation at the UE and gNB indication, are feasible. |
| Thales | Proposal 6. Consider the satellite as the reference from a timing and frequency synchronization point of view.  Proposal 11. For UL transmissions, both Doppler shifts estimation and pre-compensation should be conducted at the UE side. |
| ZTE | Proposal 5: For UL synchronization, both BS-dominated and UE-dominated mechanism can be considered. |

The companies listed in the following table, proposed to support option 2. In this case, UL Frequency compensation indication will be needed. For Ericsson, this is relevant for UEs not supporting autonomous frequency compensation. And the format of the network indication is FFS. Qualcomm proposed to support closed-loop frequency control commands by MAC-CE and consider group-common DCI for UL time and frequency control.

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| **Companies** | **Comments / Proposals** |
| Ericsson | For UE without GNSS:  Proposal 15 For UEs not supporting autonomous frequency compensation, uplink frequency accuracy needs to rely on network indication. The format of the network indication is FFS. |
| Xiaomi | Proposal 5: Pre-compensation of UL frequency offset at UE side should be supported.  Proposal 6: That network send UL frequency offset value to UE should be considered. |
| InterDigital, Inc | Proposal 2: for UL frequency offset compensation, network indicates the required frequency offset to be compensated for UL transmission is supported (Option-2). |
| OPPO | Proposal 7: UE should be provided with necessary information about the frequency offset pre-compensation. |
| Panasonic | Proposal 3: To support the frequency shift compared with UE frequency source based on the value indicated via SIB. |
| Qualcomm Incorporated | Proposal 4: In NTN, both UE autonomous and closed-loop frequency control are supported.  Proposal 5: Support closed-loop frequency control commands by MAC-CE.  Proposal 6: Consider group-common DCI for UL time and frequency control. |
| Samsung | Observation 2: Two approaches for Doppler shift compensation, i.e., autonomous compensation at the UE and gNB indication, are feasible. |
| ZTE | Proposal 5: For UL synchronization, both BS-dominated and UE-dominated mechanism can be considered. |

According to Nokia, through the detection of PSS/SSS in the DL, the UE can estimate the UE-specific frequency offset:

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| **Companies** | **Comments / Proposals** |
| Nokia | Proposal 8: The UE-specific frequency offset estimated from PSS/SSS during intial access is used to pre-compensate the PRACH transmission in the UL.  Proposal 9: The UE-specific frequency offset can be tracked using DL reference signals and should be precompensated in the UL to avoid inte-user and inter-carrier interference. |

Potential proposal 16: NR NTN UE shall be capable of using an acquired GNSS position and satellite ephemeris to calculate pre-compensation of frequency offset and apply the calculated values accordingly.

The companies to provide their comments and views in the following table:

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| **Companies** | **Comments and views** |
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# Serving satellite ephemeris format

For UL time and frequency synchronization, MediaTek and Thales proposed to broadcast the serving satellite Position/ Velocity and implicit Time[16, 23].

A format of the serving satellite ephemeris to broadcast was proposed by both companies: such format was proposed to achieve, the satellite position and velocity accuracy requirement for UL frequency synchronization (which is more constraining than the one for UL time synchronization), and to limit the signaling overhead.

Ericsson proposed to define the satellite ephemeris format according to the precision requirement related to satellite position and velocity to be met in order to achieve the requirement on UL time and frequency synchronization.

The proposals related to satellite ephemeris format are depicted in the table below:

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| --- | --- |
| **Companies** | **Comments / Proposals** |
| Ericsson | Observation 5 Satellite ephemeris with sufficient accuracy to support timing and frequency offset pre-compensation shall be made available to the NR NTN UE.  Observation 6 Satellite ephemeris with sufficient accuracy to support timing and frequency offset pre-compensation can come with low frequency updates.  Proposal 8 RAN1 to study the required accuracy of satellite ephemeris to support timing and frequency offset pre-compensation. |
| MediaTek , Eutelsat | Proposal 3: The base Station broadcast Position/ Velocity and implicit Time:  - Satellite location/velocity in ECEF coordinates  - Validity Time is the end of SFN where SIB was transmitted (from the satellite)  Proposal 4: Satellite Position and Velocity information field sizes broadcast on SIB with periodicity X  - The field size for position is 84 bits  - The field size for velocity is 60 bits  - Value of X – e.g. 200 ms, 500 ms, 1000 ms, 1500 ms, 2000 ms |
| Thales | Proposal 4. NTN SIB includes the satellite PV(T) in ECEF coordinates and the RP position in ECEF coordinates if needed  Proposal 5. Broadcast NTN SI every few seconds.   |  |  |  |  | | --- | --- | --- | --- | | Parameters | Range | Resolution | Number of bits | | Satellite Position Px, Py, Pz (ECEF) | ±50000 km | 0.4 m | 3\*28 = 84 | | Satellite Velocity Vx, Vy, Vz (ECEF) | ±8 km/s | 0.015 m/s | 3\*20 = 60 | | Reference Point Position Px, Py, Pz (ECEF) | ±6500 km | 0.4 m | 3\*25 = 75 | |

**Uplink synchronization requirements shall be defined before discussing adequate satellite ephemeris format.**

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| **Companies** | **Comments and views** |
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