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

e-Meeting, August 17th – 28th, 2020

Agenda Item: 8.4.2

Source: Moderator (Thales)

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:

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

Initial 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:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| MediaTek | Support proposal 1 |
| Intel | Support proposal 1 |
| Spreadtrum | Support proposal 1 |
| Huawei | We suspect that there may not be a conclusion in RAN WG level and the discussion may have to go back RAN plenary. On the other hand, no one is questioning we should at least support UE with GNSS capability which can be utilized for timing and frequency pre-compensation in Rel-17 NTN hence we suggest focusing on this case first. |
| Ericsson | 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.  We would like to hear more views if the simultaneous GNSS and NR operations are feasible for RRC connected mode. |
| Nokia | Tentative support for proposal 1. Prior to any further discussion, it is important that it is clarified what exactly is covered by GNSS capabilities, and especially what are the accuracy of the attributes associated to the GNSS capability (that is, whether the information is sufficiently accurate to ensure that nothing is broken when UE attempts to access the system). |
| ZTE | Support for proposal 1. And also prefer to define separate UE capability for the GNSS-equipped and pre-compensation capable UE at least with consideration on the implementation complexity.  Further discussion with consideration on the UE mode can also be considered. |
| CATT | In our understanding, in Rel-17, GNSS equipped UE should have the capability to perform timing and frequency pre-compensation. If any use cases without timing and frequency pre-compensation should be identified and resolved, it is out of Rel-17 scope. Otherwise, we need to re-open the discussion of R17 WID scope. |
| Eutelsat | Support Proposal 1. |
| QC | For Rel-17, we may first identify the GNSS capability as UE has accurate geolocation of itself.  Not sure if timing synchronization based on GNSS is required as it can use the DL signal and locations of its own and satellite to perform timing pre-compensation. |
| Loon | Support Proposal 1. |
| **Lenovo/MM** | Support proposal 1. And GNSS-based timing and frequency pre-compensation accuracy can be studied. |
| ETRI | UEs without pre-compensation capability are de-prioritized in this release. |
| Apple | Support Proposal 1 |
| Panasonic | Support Proposal 1 |
| Asia pacific telecom | Support  For GNSS initiation or resumption, it tales 30 seconds to 3 minutes. During this GNSS-off period, UE may loss pre-compensation capability. |
| OPPO | Fine with proposal 1, also agree to discuss estimation accuracy. |
| Thales | In Release 17, for NTN, we propose to assume that UEs are GNSS capable and they are able to perform timing and frequency pre-compensation using their GNSS capabilities.  We do not see under which condition a GNSS-equipped UE cannot perform timing and frequency pre-compensation for uplink synchronization based on its GNSS. |
| Sony | We think the WI should prioritize GNSS-equipped UEs with capability to perform timing and frequency pre-compensation. However, RAN1 should also define solutions with forward compatibility for UEs without GNSS and/or inaccurate or no pre-compensation capabilities. |
| SS | We have similar view as Thales and have difficulty to see the case in the proposal. However, it is OK to discuss how to do pre-compensation for the UE without GNSS. |

## Updated proposal based on company views

Based on the companies inputs, it has been observed that the vast majority of the companies support to further identify scenarios whether GNSS-equipped UEs **cannot** perform timing and frequency pre-compensation for uplink synchronization based on their GNSS capabilities.

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.

In any case, most companies are in line with supporting at least UE with GNSS capability which **can** perform timing and frequency pre-compensation for uplink synchronization based on their GNSS capabilities. The RRC modes in which the UE can perform such operation are FFS.

**Potential proposal 2: In Rel-17 NR NTN, at least support UE with GNSS capability which can perform timing and frequency pre-compensation for uplink synchronization based on their GNSS capabilities.**

|  |  |
| --- | --- |
| **Companies** | **Comments / views** |
| MediaTek | Support Proposal 1.  Support proposal 2. UE pre-compensation is not possible if UE has no way to acquire its position. GNSS capability in UE is only way widely available way for UE to acquire its position. GNSS accuracy in device is typically in the order of 1m-3 m, whereas GNSS receiver on board on satellite typically used to report satellite position for orbit control is at least as good as in device (as explained in our TDoc R1-2005496). |
| CMCC | Support Proposal 1.  **Fine with support Proposal 2,** but UE capability without timing and frequency pre-compensation cannot be precluded. There may be potential scenarios where GNSS capability cannot used for timing and frequency pre-compensation as following,   * Indoor scenario. Due to Elevation angle and link budget, LEO or HAPS keeps available, while GNSS may be out of service. * In-accurate GNSS information. |
| Intel | Support proposal 1. At least we can agree on the common assumption for such UEs (e.g. S-band and/or Ka-band; LEO and/or GEO satellites, etc.) in order to better understand the scope of work and potential enhancements.  For proposal 2, in our view it is not necessary to make such agreement since it is clear from the WID. However, we are OK with this proposa. |
| QC | Not sure the purpose of Proposal 1. If we think UEs without GNSS capability should be supported, we can just say it; if we are not clear about the exact meaning of GNSS capability, we should clarify it. Suggest the following alternative proposal:  Proposal: UEs with GNSS capability shall be capable of at least using an acquired GNSS position and satellite ephemeris for UL time and frequency synchronization.  --FFS support of UEs without GNSS position in Rel 17. |
| Panasonic | Support proposal 1 and 2. |

# 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.

|  |  |
| --- | --- |
| **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. |
| QC | Support the first bullet of Option 1 for rel-17 UEs. |
| Loon | Support both options. Option 1 is the default |

Initial 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** |
| MediaTek | Option 1 is baseline for discussion for acquisition of TA by UE.  For option 2, wait for further RAN1 discussion to identify scenarios whether GNSS-equipped UEs cannot perform timing and frequency pre-compensation for uplink synchronization based on their GNSS capabilities. This would require new RACH design. |
| Intel | Agree with MediaTek. |
| Spreadtrum | Both Option1 and option2 can be supported. |
| Huawei | Support Option 1. As replied for proposal 1, we should at least support Option 1 in Rel-17 NTN. |
| Ericsson | Our preference is along the line with Option 1. It should be noted that not only TA but also UL frequency need to be determined before PRACH transmission. For UL frequency sync, the time stamp listed in Option 1 cannot serve the purpose; instead, satellite ephemeris is needed. |
| LGE | We can further discuss regarding this issue.  As shown in potential proposal 2, for the option 1, gNB should provide a lot of information, such as serving satellite ephemeris and/or time stamp. Also, gNB should provide the TA value of feeder link in order to acquire the TA at UE side. But for the option 2, gNB only need to provide a common TA (based on the reference point). Therefore, Option 2 is preferred over the option 1.  Furthermore, If Option 1 is down-selected, the approach that the only UE specific differential TA should be compensated at the UE side is preferred. |
| CMCC | Both Option1 and Option2 can be supported. Using which Option can be left to network implementation. |
| Nokia | Support both options. Option 1 should be the baseline, but there is also a need for system operation without proper access to sufficiently accurate GNSS information, and hence there should also be support for option 2. |
| ZTE | Option1 can be prioritized and indication of TA should be supported with unified framework to support the all implementation as discussed in proposal 3 below. |
| CATT | Option 1 is preferred. But we don’t think common TA is needed to indicate since the common delay can be compensated by the gNB. And for time stamp, we need more clarifications, so far it is unclear for its effectiveness. |
| Eutelsat | Support Option 1 as baseline working assumption. We do not discount option 2 but this requires further study as it (probably) has implications for the RACH. |
| QC | Support the first bullet of Option 1. |
| Loon | Both options can be supported |
| **Lenovo/MM** | Option 1 is baseline. Option 2 can also be considered. |
| ETRI | Support option 1 as baseline |
| Apple | Option 1 is preferred. This achieves better performance of PRACH transmission. |
| Panasonic | Support option 1 |
| Asia pacific telecom | Support Option 1 for less specs impact; Option 2 shall be interpreted as NW assistant information for UE to accomplish UL and frequency pre-compensation. |
| OPPO | Both Option 1 and option 2 are considered. |
| Thales | We need at least support Option 1 in Rel-17 NTN. |
| Sony | Including option 2 would maintain forward compatibility for UEs without GNSS or incapacity to accurately calculate TA |
| SS | Both should be supported. |

## 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:

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

Initial 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:

|  |  |
| --- | --- |
| **Companies** | **Comments and views** |
| MediaTek | Support proposal 3 |
| Intel | Support proposal 3. It seems that option 3 is the most flexible, so we prefer option 3. |
| Spreadtrum | Support proposal 3 |
| Huawei | Fine with proposal 2, and option 3 is preferred as it can flexibly support all the foreseen deployment scenarios. |
| Ericsson | Option 2 and option 3 are not mutually exclusive. Existing TA mechanism already allows for configuring a common TA offset by to some extent (with very limited choices), as in the TA equation . An additional term e.g. could be further added to this equation for common TA in NTN while not impacting the usage of in existing specification. Meanwhile, NTN UE can calculate based on service link delay, for which the serving satellite is the reference point. |
| LGE | Regarding on potential proposal 3, we have some concerns for terminology definition.  In TR in SI phase, the reference point was the specific point within the cell coverage, considered as the criterion for the UE to acquire common TA. But here, the reference point is defined as the point w.r.t. which the TA is computed at UE side.  Also, in TR in SI phase, the common TA was calculated by adding the TA value of service link (i.e., between satellite and reference point) and feeder link (i.e., between satellite and GTW(or gNB)). But here, the common TA is the RTD between reference point to satellite.    Therefore, we think that it is better to define the terminology (e.g., common TA, reference point) in NTN discussion, and then we can discuss further on related issues.  Also, Figure 2 should be different from Figure 1, but it is the same here. Figure 2 seems to be wrong. |
| CMCC | Support proposal 3, with RP Option 1 & 3 preferred.  The proposed solution of using initial TA (= UE specific TA + Common TA) for UL TA pre-compensation can achieve unified design. |
| Nokia | Support proposal 1. |
| ZTE | Support proposal 3. Unified design with range of indicated common TA from 0 (e.g., corresponding to Option-2) to X (e.g., corresponding to Option-1) can support all implementation. |
| CATT | Agree with LG. Now it defines a new terminology. As stated in TR38.821, full TA=common TA+ UE specific differential TA. If UE compensates the UE specific differential TA, gNB will compensates the common TA. If full TA is compensated by the UE, then common TA can be indicated, if not, no need to indicate the common TA.  In our view, UE is only responsible to UE specific differential TA compensation. If the reference point is set in ground, gNB will compensate the feeder link delay+ a part of service link delay. If the reference point is set in satellite, gNB will compensate the feeder link delay only. In both cases, common TA is not needed to indicate. |
| Eutelsat | Support proposal 3 as first preference (on basis of flexibility). |
| QC | Support RP option 2 for simplicity and forward compatibility:   * Timing reference point needs to be clearly defined so that UEs with and without GNSS can operate together. * For feeder link (RP to satellite) with inter-satellite links, T\_0 can be dynamic and difficult for UE to acquire. |
| Loon | Support Option 3 |
| **Lenovo/MM** | Support proposal 3. And agree with LG that the terminology should be discussed. |
| ETRI | Support proposal 3. When the common TA value is 0, the corresponding parameter may not be configured. |
| Apple | Support proposal 3. Our preference is RP option 1. |
| Panasonic | Support proposal 3. And prefer RP option 3. RP location should be left for network implementation. For LEO, the feeder link delay varies and option 1 and option 2 does not work well in our view. |
| Asia pacific telecom | Support; Prefer RP Option2 for easy implementation on the UE side |
| OPPO | Support proposal 3 to further clarify these three options. |
| Thales | From our perspective, RP Option 3 can be adopted as baseline |
| Sony | The option in which the RP is on the service link is different to option 3 as discussed here. See R1-2005574.  In this option:   * Network indicates the common TA (this could be either the RTD from RP to satellite in cases where network compensates for feeder-link or RTD from RP to gNB in case where network does not compensate for feeder link RTD). * UE acquires UE-specific delay (RTD from UE to RP). GNSS-capable UEs can calculate this delay autonomously with additional ephemeris and RP location information. For forward compatibility, UEs without GNSS can acquire this delay through RACH. During the SI phase and in TR38.821 current preambles were shown to be good enough for this RACH. This is not the case for Option 3’s Fig 3 which requires much longer PRACH preambles.   Before, PRACH, UE compensates only the common TA. |
| SS | Support Option 3 |

The following proposals and observations regarding the RP were discussed by different companies:

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

Initial 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:

|  |  |
| --- | --- |
| **Companies** | **Comments and views** |
| MediaTek | Support proposal 4 |
| Intel | Support proposal 4. |
| Spreadtrum | Support proposal 4 |
| Huawei | The proposal is not clear. It will be good to clarify that the TA applied at UE for PRACH transmission can be either the sum of the UE specific TA and a common TA (if present) or only the UE specific TA, i.e. both full TA and partial TA are possible. |
| Ericsson | As mentioned in our previous comment, existing TA consists of two components Additional offset component could be considered for common TA in NTN. The autonomous TA at UE should only be applicable to for which it can correspond to RTD of service link. Network can configure a different to cope with delay variation caused by other aspects such as delay variation in feeder link, but this is up to network to decide what the network would like to take into account when (re-)configuring . |
| CMCC | Support proposal 4, with same framework of Proposal 3, i.e., using initial TA (= UE specific TA + Common TA) for UL TA pre-compensation. |
| Nokia | This will depend on the outcome of discussions for proposal 3. Various solutions for determining the UE specific TA should be considered, and it may not be associated to the RTD experienced in the service link (which might be difficult to quantify for option 1). |
| ZTE | Definition of UE specific TA is up to the decision from proposal and it can be discussed later. |
| CATT | UE specific TA is related to reference point configuration. If we agree to configure the reference point in the satellite, then the UE specific TA is equal to RTD of service link. |
| Eutelsat | Support proposal 4 (dependency on proposal 3 outcome is noted). |
| QC | Agree. This should be an outcome of RP option 2, i.e., satellite is the RP. |
| Loon | Support proposal 4 and note that it depends on proposal 3 |
| **Lenovo/MM** | Generally fine with proposal 4 |
| ETRI | Support proposal 4 |
| Apple | Support proposal 4 |
| Panasonic | Support proposal 4 |
| Asia pacific telecom | Support; this implies RP option 2, btw. |
| OPPO | Agree to have outcome of proposal 3 first before discussing proposal 4 |
| Thales | We agree with this proposal. |
| SS | This should be discussed only after we have conclusion for proposal 2. |

#### 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 |

Initial 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:

|  |  |
| --- | --- |
| **Companies** | **Comments and views** |
| MediaTek | Support proposal 5 |
| Intel | Support proposal 5 since it is valid option for implementation. |
| Spreadtrum | Support proposal 5 |
| Huawei | Support proposal 5. |
| Ericsson | Support proposal 5. |
| CMCC | Support proposal 5. |
| Nokia | Difficult to support such a proposal when accuracy and stability of “GNSS position and satellite ephemeris” has not been discussed. Further, TA is not needed for RRC IDLE and RRC inactive modes. Does this proposal relate to “UE estimate of TA to use for RACH procedure”? |
| Ericsson | Support proposal 5. |
| CATT | Support proposal 5. Also for RRC connected mode, we think autonomous TA estimation should be capable. Otherwise, frequent TAC indication will cause much trouble. |
| Eutelsat | Support proposal 5 (noting the concern of Nokia for detailed discussion). |
| QC | Support for Rel-17 UEs |
| Loon | Support proposal 5 |
| Lenovo/MM | Support proposal 5. |
| ETRI | Support proposal 5 |
| Apple | Support proposal 5. |
| Panasonic | Support proposal 5 |
| Asia pacific telecom | Support; however, if UE can find SSB in RRC\_idle or RRC\_inactive (this may be as hard as calculating TA), then a cell-specific TA can be carried in SIB. |
| OPPO | Support proposal 5. |
| Thales | We agree with the proposal 5. We consider that Release 17 UE has GNSS capability. And it can use it for autonomous acquisition of its TA in Idle/Inactive mode |
| Sony | Support proposal 5 |
| SS | OK for proposal 5. |

#### 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:

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

Initial 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:

|  |  |
| --- | --- |
| **Companies** | **Comments and views** |
| MediaTek | Autonomous TA acquisition based on GNSS and time stamp broadcast (e.g. ReferenceTimeInfo-r16) requires high-level integration of GNSS module and NR module in device and gNB. It can already be supported using Rel-16 specifications. |
| Intel | In our view TA acquisition based on GNSS and time stamp is valid option for implementation and can be considered in the NTN WI. We agree with MediaTek that such option is supported with existing specification. |
| Huawei | Our understanding is that Proposal 5 and Proposal 6 are two alternatives for autonomous TA acquisition. Since time stamp broadcast is already supported in Rel-16, this option can be up to UE implementation. However, this option would require tight interaction between GNSS module and NR module as pointed out by MTK. Moreover, the signaling overhead of time stamp cannot be neglected hence it may not be proper to mandate the support of autonomous TA acquisition based on GNSS and time stamp broadcast. |
| Ericsson | It should be noted that not only TA but also UL frequency need to be determined for UL transmission. For UL frequency sync, the time stamp cannot serve the purpose; instead, satellite ephemeris is needed. Our preference is to have a unified design to address both UL time and frequency sync. |
| CMCC | Support proposal 6.  Time stamp broadcast solution is attractive as a unified design to achieve “full-TA” pre-compensation in all potential deployment scenarios, such as, regenerative satellite payload, transparent satellite payload, multiple ISL hops, and ATG.  Regarding UL frequency compensation, as discussed in our company’s contribution (R1-2006213), network implementation solution based on DL RS detection can be considered to estimate residue DL doppler shift (i.e., the DL doppler shift after frequency pre-compensation at satellite) as well as compensate UL frequency, if both UE and gNB are keep frequency synchronization to the same universal frequency system, and if the residue DL doppler shift is less than synchronization raster. |
| Nokia | Support proposal 6. It should be noted that proposals 5 and 6 should not be seen as mutually exclusive. They can easily co-exist with different use cases. |
| ZTE | Support Potential Proposal 6. Time stamp based solution can be considered as another alternative. |
| CATT | Due to fast moving of LEO satellite, we are not sure how frequent to broadcast the reference timing information. Is there any simulation result to justify it to keep accurate TA estimation with proper stamp indication? |
| QC | This could be an option in some cases. But requires capability of frequency and time synchronization using GNSS. |
| **Lenovo/MM** | Support proposal 6. |
| Apple | The time stamp approach does not address the UL frequency synchronization issue. We may want to have a unified design for both UL time and UL frequency synchronization. |
| Panasonic | Support proposal 6 |
| Asia pacific telecom | Support proposal 6 for supporting autonomous TA acquisition. NW assistant information, e.g., satellite ephemeris, time stamp, or reference point location, may need some further discussions. |
| OPPO | Further discussion is needed thus support proposal 6. |
| Thales | Autonomous TA acquisition based on GNSS and time stamp would require high-level on integration of GNSS and NR chipset functionality in device (clock synchronization constraint), which is higher implementation complexity. |
| Sony | Support Proposal 6 |
| SS | We need further discussion for proposal 6, which can be one of the options. |

#### 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:

|  |  |
| --- | --- |
| **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. |
| Eutelsat | Agree with MediaTek. |

Initial 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:

|  |  |
| --- | --- |
| **Companies** | **Comments and views** |
| MediaTek | Support proposal 7 |
| Intel | Support proposal 7. |
| Spreadtrum | gNB indication of common TA |
| Huawei | Support proposal 7, our understanding the proposal is not to propose to down select one from the three options. Our view is that both the “common TA” and the “common TA drift rate” can be indicated to the UE. We also would like to propose a minor change:  indication of common TA drift -> indication of common TA driftrate |
| Ericsson | As mentioned in our previous comment, existing TA consists of two components Additional offset component could be considered for common TA in NTN. This common TA can be configured by network. Additionally, it could be for further study whether TA drift is helpful.  With the above, we don’t see the need of indicating gNB/NTN GW position. |
| LGE | Support potential proposal 7 |
| CMCC | Support proposal 7. |
| Nokia | Proposal is incomplete, as there are potentially additional ways for the UE to obtain the common TA for random access procedure. For non-GNSS capable UE, the above might be sufficient, but for GNSS capable UE, solutions utilizing *referenceTimeInfo* from SIB9 should not be precluded. Further, it is difficult to discuss this point when the reference point has not been determined. |
| ZTE | Support proposal 7 with indication of common TA and drift rate |
| CATT | Not support proposal 7.  UE is responsible to service link TA compensation, and network is responsible to feeder link TA compensation. Option 1 is only related to UE autonomous TA estimation, so it doesn’t mean we need to indicate common TA. |
| Eutelsat | Support proposal 7 (further discussion in RAN 1 required as is implied by the proposal). |
| QC | Feeder link delay should be handled by scheduling offset, Koffset, not TA. Small timing change for the benefit of gNB reception can be handled by TA commands. |
| Loon | Support proposal 7 |
| **Lenovo/MM** | Support Proposal 7. And a comment on indication of GW position is that the associated GW may be changed due to satellite moving for LEO scenario, which makes frequent indication of GW position and consumes large signaling overhead. |
| ETRI | Support proposal 7. It can be discussed along with the cell/beam-specific . |
| Apple | Support proposal 7. |
| Panasonic | gNB indication of common TA, but the value would not necessarily be updated according to satellite movement in case of LEO. Feeder link delay variation due to satellite movement should be handled by gNB. |
| Asia pacific telecom | Support; as NW assistant information, slightly prefer GW positions which may be pre-restored in e-sim without signaling. |
| OPPO | Support |
| Thales | We agree with the proposal. We propose that gNB/ NTN GW position should not be indicated/signaled to the UE for security reason. Also, the UE is not supposed to know the Network architecture. We consider that both common TA and common TA drift rate need to be indicated. |
| Sony | Common TA and common TA drift broadcast by SIB |
| SS | OK for the first bullet. The other two bullets needs further discussion. |

### 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:

|  |  |
| --- | --- |
| **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 Initial 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:

|  |  |
| --- | --- |
| **Companies** | **Comments and views** |
| MediaTek | First discuss Potential proposal 1 |
| Intel | Agree with MediaTek and the moderator (Thales). |
| Spreadtrum | Agree with MediaTek |
| Huawei | As replied to proposal 1, we suspect that there may not be a conclusion in RAN WG level and the discussion may have to go back RAN plenary |
| Ericsson | Agree. |
| CMCC | Both Option1 and Option2 can be supported. Using which Option can be left to network implementation. |
| Nokia | Suggest to postpone this discussion until clarification for scenarios has been obtained. |
| ZTE | Agree |
| Eutelsat | Agree with MediaTek (proposal 1 priority to discussed). |
| **Lenovo/MM** | Agree to identify the scenario where GNSS-equipped UEs can’t perform time/frequency pre-compensation. |
| Apple | We could first discuss Proposal 1 before discussing this proposal. |
| Asia pacific telecom | Agree MTK |
| OPPO | Agree with CMCC |
| Thales | Agree |
| Sony | We think the WI should prioritize GNSS-equipped UEs with capability to autonomously acquire and do timing and frequency pre-compensation. However, RAN1 should define solutions with forward compatibility for UEs without GNSS and/or inaccurate or no pre-compensation capabilities. Option 2 is such a solution. Even for GNSS-equipped UEs, Option 2 can reduce UE complexity. |
| SS | Agree |

## 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:

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

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

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

**Initial 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:

|  |  |
| --- | --- |
| **Companies** | **Comments and views** |
| MediaTek | Support proposal 8 and 9. These are key aspects of discussions for UL pre-compensation. |
| Intel | Support |
| Spreadtrum | Support |
| Huawei | Support |
| Ericsson | We agree such discussions would be helpful for determining the design. But the detailed requirements would be better for RAN4 to decide. |
| CMCC | Support proposal 8. |
| Nokia | Support proposals 8 and 9 with the addition that proposal 9 may also include “time” on top of “position” (for both UE and satellite/gNB). Further, processing latency at various locations in the system may need further discussion (conversion delay at NTN-GW, satellite, transport delays, etc.) |
| ZTE | Support proposal 8 and 9 including UE GNSS position accuracy as well satellite position accuracy based on ephemeris. |
| CATT | Support |
| Eutelsat | Support further discussion of 8 and 9. |
| QC | Support proposal 8. Support discussion on the accuracy of ephemeris so as to understand the design target for timing and frequency synchronization. |
| Loon | Support |
| **Lenovo/MM** | Support proposal 8 and 9. |
| ETRI | Support |
| Apple | Support |
| Panasonic | Support proposal 8 and 9 |
| Asia pacific telecom | Support proposal 8 and 9. Simply wonder if these are related to RAN4. |
| OPPO | support |
| Thales | We agree with both proposals. First discuss the requirements related to UL timing synchronization, then from these requirements we can determine the needed accuracy for satellite position, and UE position knowledge at UE. |
| Sony | Support both proposals 8 and 9 |
| SS | OK with proposals but do not see the need to have these proposals, which need to be discussed anyway. |

## 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.

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

**Initial 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:

|  |  |
| --- | --- |
| **Companies** | **Comments and views** |
| MediaTek | Support proposal 10. |
| Intel | Support |
| Huawei | Support |
| Ericsson | We share that the offset/margin is needed to avoid the need of negative TA in Msg2. We’re open to discuss the design options. |
| LGE | Support potential proposal 10. |
| CMCC | Support proposal 10 |
| Nokia | Prior to discussing this aspect, it is important to clarify whether the UE is allowed to transmit “too early” compared to the reference timing. By introducing UE autonomous compensation of TA there is a risk that UE will be over-compensating and hence transmit the random access preamble before it would normally be allowed to do so, thereby causing interference to other UL slots. |
| ZTE | Support to discuss it. But the introduction of “margin” is not necessary since all potential error can be handled by closed MAC CE signal. |
| CATT | Support.  If UE overestimates the TA, one gap between PRACH signal and PRACH occasion should be defined, otherwise, it will cause the interference to PUSCH signal of other user. For underestimating, it will cause GP shrinking. |
| Eutelsat | Support further discussion. |
| Loon | Support |
| **Lenovo/MM** | Support proposal 10. |
| ETRI | Support. It depends on the definition of the common TA value and the configuration of RACH occasion. |
| Apple | Support |
| Panasonic | Support proposal 10 |
| Asia pacific telecom | Support proposal 10. Btw, if RAN4 defines some requirements, then no further effort in RAN1. |
| OPPO | Discussion is needed. In our view, the offset/margin can be transparent to the UE, and up to network implementation. Example is given below, with shifted RO reception window at gNB side, it achieves a similar goal as introducing an offset at the UE side. In this case, there is no need to introduce an offset to the UE. |
| Thales | We agree with the proposal. As discussed in our TDOC, during this first acquisition, the UE can either underestimate or overestimate the TA. In case of overestimation, the PRACH sequence will be received at gNB side in advance w.r.t. the RACH occasion leading to unintended interference with previous OFDM symbols. Assuming the UEs are able to acquire their TA with a sufficient level of accuracy, then a reasonable value for the **TA offset/margin** is half the CP duration of the PRACH format configured in the cell. Since the PRACH format is already broadcasted by the gNB, it may not be necessary to broadcast the **TA offset/margin. But implementation details can be further discussed.** |
| SS | OK to discuss. |

## 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:

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

**Initial 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:

|  |  |
| --- | --- |
| **Companies** | **Comments and views** |
| MediaTek | Support proposal 11 |
| Intel | Support |
| Spreadtrum | Support |
| Huawei | Support |
| Ericsson | With UE acquiring autonomously its TA based on its GNSS, there is no need to extend the TA value range in Msg2. Need of negative TA in Msg2 can be avoided by adding an offset/margin in the autonomous TA applied before Msg1 transmission. |
| CMCC | It is related to the discussion of 4.1.2. If Option 2 (Timing advanced adjustment based on network indication) needs to be supported, it seems necessary to extend initial Timing Advance Command range. |
| Nokia | The range of the timing advance command would be depending on the associated accuracy of the applied compensation mechanisms, which in turn depends on the accuracy of the GNSS information (location and/or time) as well as the accuracy of the associated assistance information (ephemeris, referenceTimeInfo). |
| ZTE | Support |
| CATT | Support |
| Eutelsat | Support. |
| QC | Support but forward compatibility should be considered. |
| **Lenovo/MM** | Support proposal 11. |
| ETRI | Support. It depends on the accuracy of autonomous TA. |
| Apple | The TA command range extension may be needed for UE without accurate location (both UE and satellite) information. |
| Panasonic | Support proposal 11. |
| Asia pacific telecom | Support proposal 11 |
| OPPO | With UE autonomous TA acquisition, it indeed depends on the concrete TA pre-compensation solution, if full TA pre-compensation is used, we think the legacy TA command range can be reduced.  With network indicated common TA, the legacy TA command range needs to be extended. |
| Thales | From our perspective, If UE autonomously acquires its TA there is no need to extend initial Timing Advance Command range. |
| Sony | If option 2 (UE-specific timing advance is acquired by RACH), it may be necessary to extend the range. |
| SS | We think we should discuss proposal 2 first before we jump into the follow-up details. |

## 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 |

**Initial 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:

|  |  |
| --- | --- |
| **Companies** | **Comments and views** |
| MediaTek | Support proposal 12 |
| Intel | Suport |
| Spreadtrum | Support |
| Huawei | We would like to make some clarifications. Are the common TA drift and UE specific TA drift corresponding to the drift from the feeder link and service link respectively? If yes, we are fine with the proposal. |
| Ericsson | We share that autonomous TA is beneficial for maintaining valid TA. It however should be specific on which part(s) of the TA equation, , that the UE is allowed to adjust autonomously.  Our view is that the autonomous TA update is only applicable to while (and potential new offset component for common TA) should be under network control, i.e., UE does not autonomously update the offset components. |
| CMCC | Support proposal 12 |
| Nokia | Tenative support for proposal 12, but adjustment mechanisms would need to account for the inherent inaccuracy of information used for the adaptation. |
| ZTE | Support proposal 12. W.r.t the common TA drift, it should be indicated along with the common TA. For UE specific drift, can be handled by autonomous calculation. |
| CATT | UE specific TA drift can be support.  For common TA drift, it is more related to feeder link, so we don’t see the benefit because gNB can maintain the timing change of feeder link. |
| Eutelsat | Support. |
| **Lenovo/MM** | Support. And we think close-loop TA update should be considered. |
| ETRI | Support |
| Apple | Support proposal 12. |
| Panasonic | Support proposal 12. Common TA drift (corresponds to feeder link) should be managed by network. |
| Asia pacific telecom | Support proposal 12; TA drift shall be handled as NW assistant information, FFS is needed (since that satellite emphasis may also help with prediction) |
| OPPO | Support |
| Thales | We agree with proposal 12 |
| Sony | Support: Indication of a common TA drift rate per beam |
| SS | We think this is implementation issue therefore no need to be speficied. |

## Updated proposal based on company views

Based on the companies inputs, at least Option 1 described in Initial Proposal 2 should be supported.

**Potential proposal 3**: **In case UE is able to perform timing and frequency pre-compensation for uplink synchronization based on its GNSS capabilities, autonomous acquisition of the TA by the UE before PRACH transmission shall be enable.**

The support of Option 2 can be further discussed when RAN1 has identified the relevant scenarios whether GNSS-equipped UEs cannot perform timing and frequency pre-compensation based on their GNSS capabilities if any.

The companies have discussed the three options regarding the reference point to be considered for TA calculation. The best way to reach consensus seems to be the one offering the more flexible and unified framework. To do so, we suggest to avoid proposal discussing the different choices of implementation for TA calculation/definition. It is proposed to focus instead on the essential new features that need to be introduced in a flexible and unified way to support all the possible choice of implementation.

**Potential Proposal 4: In case of GNSS-based acquisition of the TA by the UE before PRACH transmission, the TA shall be calculated as the sum of the following contributions :**

* **The Common TA if indicated by the network.**
  + **Details on Common TA indication are FFS**
* **The User specific TA which is estimated by the UE based on its GNSS capability and at least one of the following network indication :**
  + **Serving satellite ephemeris**
    - **Details on satellite ephemeris indication are FFS**
  + **Time stamp broadcast (e.g. ReferenceTimeInfo-r16)**
* **The TA margin in order to account for the TA estimation uncertainty**
  + **Details on TA margin indication are FFS**

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| --- | --- |
| **Companies** | **Comments / views** |
| MediaTek | Support proposal 3. This proposal just state basic principle of UE pre-compensation of delay.  Support proposal 4. As long as the UE behavior to calculate and apply the TA is non ambiguous, there can be several options for the choice of implementation. The serving satellite ephemeris method does not require coupling of GNSS and NR modules (i.e. firmware update). BTW timestamp is already specified and is higher implementation effort in device (i.e. likely HW and architecture change).  Support proposals 5, 6  Support proposal 7, 8 |
| CMCC | Support Proposal 3.  Regarding Proposal 4,   * It is suggested to explicitly clarify the definition of “Common TA” and “UE specific TA” terminology to eliminate potential confusion as , “**Common TA is indicated by network, the value can be either positive or negative**”, and “**UE specific TA = server link RTD**”   + As noted by LGE in 1st round discussion, the terminology of “Common TA” and “UE specific TA” proposed by Moderator is different from TR 38.821. i.e., in TR for transparent payload, “Common TA = RP to satellite RTD + feeder link RTD ”, and “UE specific TA = server link RTD - RP to satellite RTD”. However, in Moderator’s proposal, “Common TA is indicated by network, the value can be either positive or negative”, and “UE specific TA = server link RTD”.   + We prefer to the new terminology and believe it can achieve unified design for both “Full TA” or “Partial TA” compensation in both payload scenarios. For example, to achieve “Full TA” compensation for transparent payload, “Common TA = feeder link RTD, then (Full) TA = UE specific TA + Common TA = server link RTD + feeder link RTD”, while to achieve “Partial TA” compensation for transparent payload, “Common TA = (-1) \* (RP to satellite RTD), where RP in the server link (e.g., at the center of satellite spot beam), then (Partial) TA = UE specific TA + Common TA = server link RTD + (-1) \* (RP to satellite RTD)”. * Time stamp broadcast is another alternative for TA pre-compensation. In our understanding, the time stamp aligns with gNB’s DL frame boundary, so the timing differential between receiving time of SIB9 at UE side and its original time derived from time stamp is equal to the full TA (i.e., server link RTD + feeder link RTD), regardless the detailed feeder architecture, e.g., transparent payload, multi-hops of ISL, etc.   Based on above discussion, we recommend to add a note “Note: Common TA is indicated by network, the value can be either positive or negative, UE specific TA is equal to server link RTD” and remove sub bullet “Time stamp broadcast (e.g. ReferenceTimeInfo-r16)” and retrieve initial Proposal 6 in 1st round discussion as following.  **Potential Proposal 4: In case of GNSS-based acquisition of the TA by the UE before PRACH transmission, the TA shall be calculated as the sum of the following contributions :**   * **The Common TA if indicated by the network.**   + **Details on Common TA indication are FFS** * **The User specific TA which is estimated by the UE based on its GNSS capability and ~~at least one of the following network indication :~~Serving satellite ephemeris**   + **Details on satellite ephemeris indication are FFS**   + **~~Time stamp broadcast (e.g. ReferenceTimeInfo-r16)~~** * **The TA margin in order to account for the TA estimation uncertainty**   + **Details on TA margin indication are FFS** * **Note: Common TA is indicated by network, the value can be either positive or negative, UE specific TA is equal to server link RTD.**   Initial 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  Not support Proposal 5. It may need further investigation whether the location information (both UE and satellite) is accurate enough.  **Support Proposal 6.**  **Support Proposal 7.**  **Support Proposal 8.** |
| Intel | Support proposals 3, 5, 6, 7, 8.  For proposal 4, we are not sure if we have not missed something in this proposal. In particular, indication of reference point location for pre-compensation may be used in NTN or something else. |
| QC | Support proposal 3. Proposal 4 needs clarifications. The intention is to have the TA of PRACH as the sum of UE calculated RTD of service link + another broadcasted value (if signaled). If so, the second part can always be included in RO configuration or indicated as a scheduling offset instead of TA. |
| Panasonic | Support potential proposal 3 and proposal 4. Regarding the TA margin in proposal 4, the necessity should be further studied. |

**Potential Proposal 5: In case of GNSS-based acquisition of the TA by the UE before PRACH transmission, the initial Timing Advance Command range does not need to be extended.**

**Potential Proposal 6: RAN1 to further investigate the following enhancement on the maintenance phase of the timing advance:**

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

As suggested by all the interested companies, RAN1 shall further discuss the requirements related to UL time synchronization and their implication on the solutions proposed for TA autonomous acquisition and maintenance.

**Potential Proposal 7: RAN1 to further discuss the requirements related to UL time synchronization.**

**Potential Proposal 8: RAN1 to further discuss the implication of UL timing alignment requirements on the expected accuracy of :**

* **The satellite position knowledge at UE side**
* **The UE position knowledge at UE side**

# 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. |

**Initial 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:

|  |  |
| --- | --- |
| **Companies** | **Comments and views** |
| MediaTek | Support proposals 13 |
| Intel | Support |
| Spreadtrum | Support |
| Huawei | We still would like to make some clarification on the proposal. Is there an underlying assumption that post-compensation of common Doppler frequency shift on UL will be applied accordingly? |
| Ericsson | It is not clear to us the need of indicating pre-compensation of common Doppler frequency shift on DL transmission. We think this can be made transparent to UE.  For example, suppose the carrier frequency is 2 GHz and for simplicity assuming DL and UL frequency are both at 2 GHz.   * Without pre-compensation, the UE would lock to a frequency of 2 GHz + 48 kHz Doppler shift. With pre-compensation of 40 kHz, the UE would lock to a frequency of 2 GHz + 8 kHz Doppler shift. * Then comparing it to the reference frequency (2 GHz) from GNSS, the UE knows it should transmit in UL frequency of 2 GHz – 8 kHz.   Then all the UE’s UL signals would arrive at gNB at 2 GHz + 40 kHz. Then gNB could perform a post-compensation of 40 kHz back to 2 GHz. |
| CMCC | It is not clear to us the need of indicating pre-compensation of common Doppler frequency shift on DL transmission.  Instead, indication of post-compensated common Doppler frequency shift on UL transmission seems more proper. |
| Nokia | Whether or not the system is operating earth-fixed or earth-moving beams, this should be transparent to the UE. Hence, any solution for indicating the applied Doppler shift should be common to any scenario. Further, it is not completely clear whether this information of the compensated values need to be communicated to the UE. |
| ZTE | Such pre-compensation and post-compensation can be transparent to UE but indication of such value is helpful to improve the beam switching/handover. |
| CATT | In DL Doppler frequency shift compensation, it can be transparent to UE. UE can estimate the residual frequency offset based on DL signal, so what is the benefit to indicate the DL common frequency compensation information?  Instead, we think UL post-doppler compensation should be indicated to UE, because UE can compensate partial Doppler shift or full Doppler shift depending on gNB post-compensation way. We share similar view with CMCC:  **Support indication of UL post-compensated common Doppler frequency shift.** |
| Eutelsat | Support the proposals. |
| QC | Support the signaling of frequency shift applied, i.e., bullet 2. |
| Apple | Support |
| Panasonic | Support the indication of frequency shift from gNB. The value should be up to gNB implementation. |
| Asia pacific telecom | Support proposals 13; however, based on our understanding, this might be useful only to support a case of beam diameter = 1000 km. In Table 6.1.1.1-8 in TR 38.821, for beam diameter < 90km, there is no need to enhance because max Doppler shift is < 3ppm, if pre/post compensation mechanism is assumed at satellite payload side. Rel-15/16 NR SSB can be reused. |
| OPPO | Propose to further discuss the feasibility pointed by Ericsson, Nokia and CATT. |
| Thales | We agree with this proposal. In case of Earth -fixed beam, the common Doppler is time-variant. It might be challenging to indicate it to the UE. In this case we believe that indicating the position of the RP w.r.t. which the DL Doppler pre-compensation is performed will be enough.  In case of Earth moving cell, the common Doppler shift value is fixed per beam. Indicating the common Doppler shift value is the best option is this case. |
| SS | It is not clear why we need two solutions. |

## 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. |

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

**Initial 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:

|  |  |
| --- | --- |
| **Companies** | **Comments and views** |
| MediaTek | Support proposal 14 and 15. These are key aspects of discussions for UL pre-compensation. |
| Intel | Support |
| Spreadtrum | Support |
| Huawei | Support |
| Ericsson | We agree such discussions would be helpful for determining the design. But the detailed requirements would be better for RAN4 to decide. |
| CMCC | Support proposal 14. |
| Nokia | Support proposals 14 and 15. |
| ZTE | Support proposals 14 and 15. |
| CATT | Support 14 and 15 |
| Eutelsat | Agree with MediaTek. |
| Loon | Support |
| **Lenovo/MM** | Support proposal 14 and 15. |
| Apple | Support |
| Panasonic | Support |
| Asia pacific telecom | Support proposal 14 and 15; simply wonder if RAN4 shall be involved in this requirement issues. |
| OPPO | Support |
| Thales | We agree. First discuss the requirements related to UL frequency synchronization, then from these requirements we can determine the needed accuracy of satellite position, satellite velocity and UE position knowledge at UE. |
| SS | OK to discuss but as mentioned earlier, we do not see the need to make the agreements since it will be discussed anyway. |

## 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. |

Initial 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:

|  |  |
| --- | --- |
| **Companies** | **Comments and views** |
| MediaTek | Support proposal 16 |
| Intel | Support |
| Spreadtrum | Support |
| Huawei | Support |
| Ericsson | Support |
| CMCC | Support proposal 16. |
| Nokia | Tentative support for proposal 16, conditioned that the proposal is relevant only for UL frequency pre-compensation such that UL receptions are received at satellite with same doppler offset (whether that is fully compensated or not need further discussions). At this point, we should take care that we do not preclude GNSS capable UE with incomplete GNSS information from accessing the system. For DL, the UE will need to be able to synchronize to the SSB to read PSS/SSS/PBCH and associated SIBs to acquire the needed information. |
| ZTE | Support |
| CATT | Support |
| Eutelsat | Support. |
| QC | Support for Rel-17 UEs |
| Loon | Support |
| **Lenovo/MM** | Support. |
| Apple | Support |
| Panasonic | Support |
| Asia pacific telecom | Support |
| OPPO | Support |
| Thales | We support the proposal |
| SS | We think the condition of UE being capable of using an acquired GNSS position and satellite ephemeris should be discussed and agreed first. |

## Updated proposal based on company views

As suggested by all the interested companies, RAN1 shall further discuss the requirements related to UL frequency synchronization.

**Potential Proposal 9: RAN1 to further discuss the requirements related to UL frequency alignment.**

**Potential Proposal 10: 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**.

Additionally, based on companies views, the UE shall not autonomously compensate frequency errors introduced by the satellite transponder and frequency offset on the feeder link.

**Potential Proposal 11: UE does not autonomously compensate frequency errors introduced by the satellite transponder and frequency offset on the feeder link.**

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| **Companies** | **Comments / views** |
| MediaTek | Support proposals 9, 10  On proposal 11, it is not needed because it is not possible for UE to autonomously compensate frequency errors introduced by the satellite transponder and frequency offset on the feeder link. |
| CMCC | Support Proposal 9, 10, 11.  On Proposal 11, gNB can compensate frequency error on the feeder link. |
| Intel | Support proposal 9 and 10.  It is not clear if UE can distinguish constant frequency error and Doppler shift so we do not support proposal 11. |
| QC | An agreement is needed exactly because it is difficult to compensate the Doppler in the feeder link. This concerns how UE calculates the frequency to be pre-compensated for PRACH and also frequency tracking when connected. Alternative to the above, NW can broadcast a feeder link Doppler or gateway geolocation.  To be more specific, we propose to revise the Proposal as  **Proposal 11: When calculating the frequency compensation in the UL, UE assumes the Doppler on the feeder link is 0.**  Or to unify timing and frequency synchronization, we propose the following  Proposal: For UL time and frequency synchronization, UE assumes feeder link delay is 0 and Doppler is 0.   * FFS additional time and frequency compensation signaled by the Network |
| Panasonic | Support proposal 9, 10 and 11. |

All the interested companies seemed to be in line with the proposal :

Potential proposal 12: In case UE is able to perform timing and frequency pre-compensation for uplink synchronization based on its GNSS capabilities, 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.

Finally, based on the companies feedback, it shall be further discussed whether Common Doppler indication is needed to assist UE UL frequency synchronization in case of pre-compensation of Common frequency shift on DL transmission. Moreover, it shall be further clarified whether post-compensation shall be also assumed in case of pre-compensation of Common frequency shift on DL transmission.

**Potential Proposal 13: RAN1 to further discuss whether indication of the pre-compensated Common Frequency Offset on DL transmissions is needed or can be transparent to the UE.**

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| **Companies** | **Comments / views** |
| MediaTek | Support proposal 12. Same comment as Proposal 3. This proposal just state basic principle of UE pre-compensation of frequency offset.  Support proposal 13. This should be at least an option. In Rel-16 SI, it was agreed that common frequency offset should be compensated by the gNB on access link to ensure backward compatibility with DL SSB specifications and implementations in device. It needs to be indicated so UE behavior is not ambiguous and UE knows it only needs to pre-compensate the differential frequency offset. |
| CMCC | Support Proposal 12.  On proposal 13, fine for further study, although it is not clear to us the need of indicating pre-compensation of common Doppler frequency shift on DL transmission, since UE can estimate the residual frequency offset based on DL signal without knowledge of pre-compensated common doppler frequency shift at gNB side. |
| Intel | Support proposal 12 and 13. |
| QC | Proposal 12 is obvious. Not sure why do we need this proposal. Maybe we can modify the proposal:  UE with GNSS capability 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.  Support Proposal 13 but not for UEs with GNSS capability. |
| Panasonic | Support proposal 12 and 13. On proposal 13, the frequency shift value UE shall apply should be indicated to UE whatever DL pre-compensated value or post-compensated value at gNB. |

**Potential Proposal 14: RAN1 to further discuss whether Common Doppler post-compensation on UL transmissions is needed.**

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| **Companies** | **Comments / views** |
| MediaTek | Support proposal 14. The other option to whether indication of the pre-compensated Common Frequency Offset on DL transmissions in Proposal 13 is that implementation of pre-compensation and post-compensation on the common frequency offset at BS side for DL and UL, respectively, as baseline assumption as commented by ZTE. Both options are fine for device and would not impact SSB specifications and implementation. |
| CMCC | Fine for further study, and we prefer to indication of post-compensated common Doppler frequency shift on UL transmission.  If gNB performs post-compensation and do not indicate it to UE, the UE may over-compensate doppler frequency shift on UL transmission, which may cause confusion. |
| Intel | Fine to study this further. |
| QC | It’s should be up to Network. If overcompensation is a concern, network can always signal a common offset in addition to UE calculated one. Network does not need to indicate the reason of this common offset. |
| Panasonic | Support proposal 14. The frequency shift value UE shall apply should be indicated to UE whatever DL pre-compensated value or post-compensated value at gNB. |

# 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 | |
| Loon | HAPS ephemeris broadcast needs to be considered as well. Our proposal is in R2-2006924 . Ephemeris format for HAPS:  name: timestamped\_coordinates  type: array of compound fields [max length of 4]  subfield[0]: **longitude\_deg (**double precision)  subfield[0]: **latitude\_deg** (double precision)  subfield[0]: **height\_m** (double precision)  subfield[0]: **timestamp** (uint64)  Subfield[0]: **validity\_timer** (uint64)  Description: Cartographic coordinates are relative to the WGS84 reference ellipsoid of the Earth’s surface. Longitude and latitude are in degrees and height is the distance, in meters, above the WGS84 ellipsoid surface. Timestamp is a count of microseconds since the Unix epoch based and presumes that leap seconds are smeared according to <https://developers.google.com/time/smear>.  Validity timer is used to indicate how long the HAPs is expected to be at that location |

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

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| **Companies** | **Comments and views** |
| MediaTek | Uplink synchronization requirements if agreed will define the accuracy for the orbit state vectors (satellite position and velocity) or orbit parameters from which sate vectors can be derived to determine delay and frequency offset. The granularity and update frequency are important aspect of discussions with update of several seconds or up to several minutes for “real-time” state vectors or orbit parameters needed for accurate UE pre-compensation. |
| Intel | Agree with the suggestion from the moderator (Thales) |
| Huawei | Agree |
| Ericsson | Agree.  Satellite ephemeris can be represented in different forms including orbital elements and orbital state vector. Different forms of orbit representation can be translated to each other. 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 times different from the reference time. Ephemeris is needed not only for the serving satellite but also other satellites for the purposes of e.g. RRM measurements, idle/inactive measurements, handover, etc.  So, a holistic view should be taken when deciding satellite ephemeris format. Whichever format is chosen, we believe that NTN UE should have the capability of satellite trajectory calculation based on a provided orbit representation at a reference time. This should be formalized as a basic design assumption. |
| CMCC | Agree |
| Nokia | Prior to making any agreements on this topic, it is important to evaluate (a) which accuracy is needed from UE GNSS receiver side to utilize this information, (b) which update rate from SIB broadcasting point of view is needed, and (c) whether the additional DL broadcasting overhead is reasonable. |
| ZTE | Agree. Satellite ephemeris based on orbit dynamic model is preferred to acquire the real-time PV as well as the predicted PV in later time. |
| CATT | Synchronization requirements are linked to ephemeris information accuracy. So we support to discuss the synchronization requirements firstly, and then further discuss the ephemeris information indication.  Regarding the orbit parameters format, conventional GNSS parameters for positioning should be taken as the baseline. |
| Eutelsat | Agree with MediaTek. |
| QC | Agree |
| Loon | Agree |
| ETRI | Agree |
| Apple | Agree |
| Panasonic | Agree |
| Asia pacific telecom | Agree; meanwhile RAN2 email discussion [AT111e] [106] [NTN] Idle mode issues (ZTE) has an issue on orbital parameters vs. ECEF. We may wait for some inputs from NTN CP guys. |
| OPPO | Agree |
| Thales | We agree. First discuss the requirements related to UL frequency synchronization, second, from these requirements we can determine the needed accuracy for satellite position, satellite velocity and UE position knowledge at UE. Then, we can derive the suitable satellite ephemeris format taking into account the signaling overhead on the SIB |
| SS | Agree. |

## Updated proposal based on company views

All the companies agree that **uplink synchronization requirements shall be defined before discussing adequate satellite ephemeris format.**

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15. Asia Pacific Telecom co. Ltd, R1-2006641 Discussion on UL time and frequency synchronization for NTN.
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17. Nokia, R1-2006422 Discussion on UL time and frequency synchronization for NTN.
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