3GPP TSG RAN WG1 Meeting #104bis-e R1-210XXXX

April 12th – April 20th, 2021

Agenda Item: 8.15.2

Source: Moderator (MediaTek)

Title: Summary #2 of AI 8.15.2 Enhancements to time and frequency

synchronization

Document for: Discussion and Decision

# Introduction

At the RAN#86 meeting, a new Study Item was approved for IoT Non Terrestrial Network (NTN) and revised in RAN#91 [1]. There was an email discussion on [91E][42][NTN\_IoT\_Roadmap] In RAN#91 with moderator summary and final proposal for GTW input in [2].

In RAN#91-e GTW session, the Chairman endorsed a Way Forward Proposal in [3] on email discussion on [50][New\_proposals\_approval]. This included guidance from RAN Chairman for NTN NR and NTN IoT as follows

* *RAN#92E (June) to finalize the scope and project plan to deliver the essential minimum functionality of both NTN NR and NTN IoT (both NB-IoT and eMTC) within the existing TU allocations*
* *Detailed scoping exercise (NTN NR WID revision, NTN IoT WID approval) to be undertaken at RAN#92E (June)*

In this meeting, company views on UL synchronization for IoT NTN are summarized and observations/proposals on identified issues are made. Observations and proposals in Company’s TDoc contributions are listed in the Appendix.

# Initial Round Discussion

In RAN1#104e IoT NTN specific issues were identified as follows:

* GNSS Measurement window
* GNSS position fix impact on UE power consumption
* NTN SIB reading impact on UE power consumption
* Long UL transmission on PUSCH
* Long UL transmission on PRACH
* DL synchronization

## GNSS measurement window

The following agreement was made in RAN1#104e:

Agreement:

* *Discuss whether GNSS measurement window is needed and beneficial for initial access.*

A note in the Rel-17 IoT NTN SID states that assumption of GNSS capability is that UE can estimate and pre-compensate timing and frequency offset with sufficient accuracy for UL transmission.

*NOTE: GNSS capability in the UE is taken as a working assumption in this study for both NB-IoT and eMTC devices. With this assumption, UE can estimate and pre-compensate timing and frequency offset with sufficient accuracy for UL transmission. Simultaneous GNSS and NTN NB-IoT/eMTC operation is not assumed.*

Since simultaneous GNSS and NTN NB-IoT/eMTC operation is not assumed, it seems reasonable to discuss need for GNSS measurement window when IoT module is switched off.

Companies supportive of GNSS measurement window:

* OPPO (usage restriction of IoT / GNSS), Apple (initial access) mentioned GNSS window is needed
* ZTE proposed study the configuration of time gap for GNSS positioning between PDCCH and before the PUSCH

Companies not supportive of GNSS measurement window: CATT, CMCC, MediaTek, Ericsson, APT

* CATT proposed to study the mechanism to trigger GNSS measurement when UE initiates the wakeup from PSM state or inactive state of eDRX.
* CMCC, MediaTek proposed it is up to UE implementation to acquire GNSS fix during (e)DRX
* Qualcomm proposed at least for short, sporadic connections, a SIB containing satellite location information is not read in connected mode. This would suggest that acquiring GNSS position in connected mode is not necessary since ephemeris may not be valid.
* Ericsson proposed to wait for RAN2 progress on GNSS measurement window



Figure 3 GNSS signal reception and IoT UE wakeup (CATT [7])

The moderator view is that there is no clear consensus and understanding on the GNSS measurement window. More discussions are needed. It needs to be clarified whether GNSS measurements are for idle UE or connected UE. Measurement gap Repetition Period of 40 ms or 80 ms are currently specified for inter-frequency and inter-RAT measurements. A measurement gaps of 1s, 2s, or even larger is a significant change in specifications which may require at least be discussed in RAN2 and RAN4.

***Initial proposal – Section 2.1:***

* ***Companies are encouraged to further discuss and comment on GNSS measurement window***
  + ***Assumption for duration of GNSS measurements***
  + ***Assumption for Measurement Gap Repetition Period and measurement gap duration***
  + ***Triggering mechanisms for GNSS measurements***

|  |  |
| --- | --- |
| Company | Comments |
| CATT | GNSS measurement will impact the synchronization procedure and UE power consumption. If GNSS measurement duration is long, it is better to let UE do this measure firstly and conduct the DL and UL synchronization procedure later. Triggering the GNSS measurement can be coming from one DRX timer or one TAU timer. Since IoT UE will send a burst packet in most of time, performing GNSS measurement is not desired in RRC-connected mode. Some comments for the following technical points:   * + ***Assumption for duration of GNSS measurements***   Proposal: Could be a few seconds level.   * + ***Assumption for Measurement Gap Repetition Period and measurement gap duration***   Proposal: Not need to define this measurement gap   * + ***Triggering mechanisms for GNSS measurements***   Proposal: Use one (e)DRX timer or one TAU timer |
| GateHouse | It is our view that:   1. GNSS measurements can be performed prior to the expiration of T3412 timer or a pending UL TX.    1. **Stationary devices may not have a GNSS module but are provisioned with a position**. So they have no need to wait.    2. This moves **complexity to the network/protocol-side** which can seemingly be solved easily on the UE-side.    3. **GNSS measurements need only be made when the UE has moved a significant distance**. So it is only a concern for PSM and idle DRX. The period that the UE is idle in iDRX and PSM should be large enough to perform the GNSS measurements.    4. If the last point (1c) is not true for iDRX, then Gatehouse supports redesigning the iDRX mechanism with idle periods long enough to allow for GNSS measurements. |
| ZTE | We prefer to define the GNSS measurement window, which is used to ensure the accuracy for following Uplink transmission, e.g., before Msg-1. Meanwhile, for the PMS mode and eDRX, the additional definition of the dedicated GNSS measurement window is preferred to ensure the better configuration for whole procedure.   1. W.r.t the duration of measurement: It should at least cover the required time for hot and warm start, e.g., up to 5s. But according to the RAN4 requirement listed in 36.171, the max response time can be  | System | Success rate | 2-D position error | Max response time | | --- | --- | --- | --- | | All | 95 % | 15 m | 20 s |  1. W.r.t the ***Repetition Period and duration:*** if only short transmission is supported and the required gap for measurement can be configured in aperiodic way. 2. W.r.t the triggering mechanism: It can be triggered for specific event, e.g., wake-up for transmission |
| Xiaomi | We propose to wait for RAN4 and RAN2 progress on GNSS measurement window. |
| Eutelsat | We see the timing of the GNSS measurement and its latency/accuracy to be the important aspects. A GNSS measurement window need not be defined as long as these requirements can be fulfilled.  We agree with Qualcomm that if the SIB cannot be read in connected mode there is no motivation to obtain an updated GNSS fix in connected mode. |
| Huawei， HiSilicon | There are several factors that will have an impact on how frequent the UE need to perform GNSS measurement and the duration of GNSS measurement, such as packet arrival rate, UE speed, UE hardware/software implementation, etc.  As an example, a stationary UE may need to do GNSS measurement only once while a moving UE may need to perform GNSS measurement when a significant position change occurs. The duration of GNSS measurement depends on scenarios, e.g. cold/warm/hot start, and also relate to hardware implementation. The duration can range from 1s to tens of seconds. Therefore, it may be challenging to configure GNSS measurement duration, Measurement Gap Repetition Period and measurement gap duration as well as the triggering mechanisms.  As it is now we have a preference to leave GNSS measurement to UE implementation but we are also open to further discussions on whether time/synchronization accuracy can be fulfilled without introducing the GNSS measurement window. |
| CMCC | In our view, a UE can first measure GNSS, and then do PSS search, SIB read, and small packet transmission. In fact, all the procedures of GNSS measurement, PSS search and SIB read can be done up to UE’s implementation in the preparation period before DRX active duration, and no specification change is needed.    Thus, we share similar comments for the following technical points with CATT:   * + ***Assumption for duration of GNSS measurements***   Could be a few seconds level.   * + ***Assumption for Measurement Gap Repetition Period and measurement gap duration***   Not need to define this measurement gap.   * + ***Triggering mechanisms for GNSS measurements***   It can be triggered for specific event, e.g., wake-up for transmission. |
| Apple | We support that the GNSS measurement window is needed in initial access. The duration of GNSS measurements could be about 1-2 seconds. |
| Qualcomm | 1. ***Assumption for duration of GNSS measurements***   We can capture the different assumptions on measurement durations that different companies have proposed (for evaluations) in the TR—including, durations depending on whether it is a hot, cold, warm, measurement, etc. But **we don’t think there is need for any specification in Release 17 w.r.t the duration of GNSS measurement**—especially since Rel 17 is focused on the “short, sporadic connection” case. However, with future releases in mind—including future support of long connections, documentation of observations from different companies is useful.   1. ***Assumption for Measurement Gap Repetition Period and measurement gap duration***   Any proposals in this regard can be captured in the TR as “potential solutions” for maintaining time/frequency synchronization during long connections. However, for normative work in Rel 17—which would focus on the “short, sporadic connection” case—**we do not think there is a need to do GNSS measurements in connected mode in Rel 17.** Hence, discussion on measurement gaps should be deferred for future work on “long connections”, with potential documentation in the TR.   1. ***Triggering mechanisms for GNSS measurements***   Similar to above comment on measurement gaps, we believe that for the “short, sporadic connection” case prioritized for Release 17, a reasonable assumption is that the UE reads GNSS before every connection. As a result, **we may not need to specify explicit triggering mechanisms for Release 17**. However, more involved mechanisms may be applicable for **“long connections”,** such as those proposed in **Section 2.8.2** (Non-RLF mechanisms for handling outdated GNSS information). These, and other valid mechanisms for triggering and maintaining GNSS synchronization during long connections should be documented in the TR. |
| MediaTek | 1. ***Assumption for duration of GNSS measurements***   Hot start 1 s, warm start 5 s   1. ***Assumption for Measurement Gap Repetition Period and measurement gap duration***   For short sporadic packet transmissions, we see no need for new measurement gaps in connected. This can be de-prioritized in Release-17.  Further, measurement gap duration in connected are maximum 80 ms. Having a new measurement gap with 1 second or longer in connected should be discussed in RAN2 in case considered for other types of traffic in future releases. At least DRX / eDRX in connected should be considered as a possible solution.   1. ***Triggering mechanisms for GNSS measurements***   For short sporadic packet transmissions, UE can acquire GNSS position and read NTN SIB carrying ephemeris before moving to connected. Triggering mechanisms can be de-prioritized in Rel-17. |
| Spreadtrum | * + ***Assumption for duration of GNSS measurements***   The duration depends on scenarios, e.g. cold/warm/hot start, which can range from 1s to tens of seconds.   * + ***Assumption for Measurement Gap Repetition Period and measurement gap duration***   Not need to define this measurement gap in connected mode in Rel 17.   * + ***Triggering mechanisms for GNSS measurements***   UE should perform GNSS measurements before moving to connected mode. |
| APT | Q1: 5s (warm)  Q2: No GNSS and no ephemeris reading in RRC\_ONNECTED for NB-IoT (no spec impact)  Q3: prior to cell search or at least before NPRACH transmission for NB-IoT (no spec impact)  According to R4-2104834, GNSS is operated in L band, NTN IoT might be in S band. There is no interference between them. Considering half-duplex FDD, if GNSS and IoT have separated RF modules, then TDD between GNSS and IoT modules seems non-necessary. |
| Nokia, NSB | We think GNSS measurement window is needed for UL sync before UL transmission.  Another comment is it is mainly related to RAN2, while RAN1 should start discussion after RAN2 has some progress. |
| SONY | GNSS measurement window is needed for UL sync before UL transmission.  For short sporadic transmissions that are mobile originated, UE implementation can determine when to perform a GNSS measurement.  For any form of mobile terminated transmission where the UE doesn’t have accurate GNSS measurement previosuly, there should be a GNSS measurement gap between the initial DL transmission to the UE (e.g. paging) and the initial UL transmission. This avoids the UE having to do a GNSS measurement “just in case” it is paged.   * ***Assumption for duration of GNSS measurements***   Hot start 1 s, warm start 5 s   * ***Assumption for Measurement Gap Repetition Period and measurement gap duration***   Measurement gap duration should be sufficient to handle the measurement time of 1s (hot start) / 5s (warm start).  We think that measurement gap repetition is not necessarily required. In connected mode, the UE should be able to handle timing advance by means other than using GNSS measurements   * ***Triggering mechanisms for GNSS measurements***   For short sporadic *mobile originated* packet transmissions, UE can acquire GNSS position and read NTN SIB carrying ephemeris before moving to connected.  For short sporadic *mobile terminated* packet transmissions, UE can acquire GNSS position after decoding an initial DL message (e.g. paging, {M/N}PDCCH.  In some ways, we are OK considering GNSS measurement windows as a Rel-18 enhancement. i.e. GNSS measurement windows are not essential minimum functionality. The UE can function without GNSS measurements windows. There will be an impact on UE power consumption, to a greater or lesser extent, from having to perform GNSS measurements “just in case”. |
| Ericsson | To reduce battery consumption, it is beneficial if the UE can perform GNSS measurements after a paging occasion and only if it has been paged. A GNSS measurement window needs to be defined only if it is not possible to configure the existing timers such that there is a sufficient gap to accommodate GNSS acquisition after decoding the paging message and before initiating UL transmission. Typical times for GNSS measurements could be 1 s for hot start and 5 s for warm start.  Repetition period: The intention with this question is not clear to us. For initial access there is no need for a Measurement Gap Repetition Period.  Triggering mechanisms: The intention with this question is not clear to us. |

### FIRST ROUND – GNSS measurement window

CATT, GateHouse, ZTE, Xiaomi, Eutelsat, Huawei, CMCC, Apple, Qualcomm, MediaTek, Spreadtrum, APT, Nokia, SONY, Ericsson provided comments

Assumption for duration of GNSS measurements

* CATT, CMCC (a few second level), , Apple (1 to 2 seconds), ZTE (hot start and warm start up to 5s), SONY, MediaTek, Ericsson (hot start 1s, warm start 5s), Huawei (1 to 10 seconds), Qualcomm (depends on hot, cold, warm measurements), Spreatrum (1s to tens of seconds), APT (warm)
* ZTE mention max time can be up to 20 seconds (RAN4 requirement listed in 36.171 Section 6.2.1 minimum requirement for nominal accuracy of GNSS is as below)

Table 6.9: Minimum requirements

| System | Success rate | 2-D position error | Max response time |
| --- | --- | --- | --- |
| All | 95 % | 15 m | 20 s |

Qualcomm mention different assumptions can be captured in TR, but no need for specification for duration of GNSS measurement.

Assumption for Measurement Gap Repetition Period and measurement gap duration

* Companies that do not see need for GNSS window measurement:
  + CATT, Gatehouse, MediaTek, CMCC (make measurements before DRX active duration)
  + Spreadtrum (not needed), Eutelsat (if SIB not read in connected mode, no motivation to get a GNSS position fix)
  + Huawei (challenging configuration, leave GNSS measurements to UE implementation),
  + APT (no GNSS and no ephemeris reading in connected)
  + Qualcomm (focus on short, sporadic connection, defer discussion for future work on long connections with potential documentation in TR),
  + SONY (up to UE implementation for sporadic short transmission),
  + Ericsson (configure the existing timers such that there is a sufficient gap to accommodate GNSS acquisition after decoding the paging message and before initiating UL transmission)
* Motivation for GNSS measurement window:
  + ZTE (GNSS measurement window is used to ensure the accuracy for following Uplink transmission, e.g., before Msg-1. dedicated GNSS measurement window is preferred to for better configuration for whole PSM mode and eDRX procedure)
  + Apple (initial access assuming 1-2 s GNSS measurement)
  + Nokia (initial access)
  + SONY (avoid just in case GNSS measurement to ensure there is sufficient gap in case UE is paged)

Ericsson commented to reduce battery consumption, it is beneficial if the UE can perform GNSS measurements after a paging occasion and only if it has been paged.

Triggering mechanisms for GNSS measurements

* Supportive: CATT ((e)DRX timer or TAU timer), Spreadtrum, CMCC (wake-up for transmission), APT (before cell search or at least before RACH), Qualcomm (for long connection can be documented in TR)
* Not supportive: MediaTek, Qualcomm, SONY for sporadic short transmission case prioritized in Rel-17

Xiaomi commented to wait for RAN4 and RAN2 progress on GNSS window.

Nokia commented it is mainly related to RAN2, while RAN1 should start discussion after RAN2 has some progress.

SONY mentioned GNSS measurement windows as a Rel-18 enhancement may be considered. i.e. GNSS measurement windows are not essential minimum functionality. The UE can function without GNSS measurements windows. There will be an impact on UE power consumption, to a greater or lesser extent, from having to perform GNSS measurements “just in case”.

Moderator view based on comments is that GNSS measurement duration can be up to 10 seconds. There is not enough consensus on motivation and solution to ensure there is a sufficient gap for GNSS measurements in idle UE or connected UE. This depends on the scenarios and understanding of legacy procedures (i.e. configuration of paging, DRX timers) .The use case for triggering mechanisms should be further discussed. Proponents of GNSS measurement window are encouraged to discuss offline for more understanding and support.

***FL recommendation – Section 2.1.1:***

* ***Companies are encouraged to further discuss scenarios, motivation and solution to ensure there is a sufficient gap for GNSS measurements in idle UE or connected UE and to discuss offline to align on understanding of legacy procedures (i.e. configuration of paging, DRX timers). Further consider whether issue should first be discussed in RAN2.***

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| Company | Comments |
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## GNSS Position fix impact on UE power consumption

The following agreements were made in RAN1#104e

Agreement:

*Study potential impact of GNSS Position fix on UE power consumption using battery life methodology in Rel-13 TR 45.820 (Section 5.4)*

*FFS: Details of the study*

Agreement:

*For the study of potential impact of GNSS Position fix on UE power consumption consider at least the following parameters*

* *GNSS power consumption value*
* *GNSS position Time To First Fix*

In TR 45.820, Section 5.4 provides a table 5.4-1 with Key input parameters for energy consumption and Section 7.2.4.5.2 provide power consumption assumptions for energy consumption model.

Table 5.4-1: Key input parameters for energy consumption analysis

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| (1) Battery capacity  (Wh) | (2) Battery power during Tx  (mW) | (3) Battery power for Rx (mW) | (4) Battery power when Idle but not in PSS (mW) | (5) Battery power in Power Save State (PSS) (mW) | (6) Time between end of IP packet carrying "report" and start of IP packet carrying "ack" on radio (ms) | (7) Number of reports per day |
| 5 |  |  |  | [0,015] | 1000 |  |
| For each report (refer to Figure 5.4-1): | | | | | | |
| (8) Rx time from PSS exit to re-entry into PSS  (ms) | (9) Idle time from PSS exit to re-entry into PSS  (ms) | (10) Tx time from PSS exit to re-entry into PSS  (ms) | (11) Time from last Rx or Tx activity to entry into PSS1  (ms) |  |  |  |
|  |  |  | 20000 |  |  |  |

Table 7.2.4.5-1: Power consumption assumptions

|  |  |  |
| --- | --- | --- |
| ***Activity*** | ***Power consumption***  ***(mW)*** | ***Comments*** |
| TX active | 545 | Transmitter active at +23 dBm, assuming 44% PA efficiency and 90 mW for other analog and baseband circuitry |
| RX active | 90 | Analog RF and digital baseband processing for active receiver |
| Idle  (light sleep) | 3 | Maintenance of precision oscillator reference for RF synthesizers |
| Deep Sleep | 0.015 | Low power crystal, sleep counters and state machine |



Huawei mention conditions for GNSS TTFF with cold start, warm start, hot start:

* The first is cold start with which no almanac information is stored in the receiver. The UE have to search signals from all the possible satellites and at least 4 satellites are needed for the positioning. Therefore, the duration will be affected by the rate of GNSS signal transmission and quality of reception. The time duration of cold start can range from tens of seconds to more than ten minutes. The typical values of cold start is 30 s if the GNSS signal is received with not much interruption.
* The second start is warm start which is based on the assumption that the some ephemeris information and clock correction data is already obtained. With some available information, the positioning time will be reduced to several seconds.
* The third start is hot start which is based on the assumption that GNSS receiver has valid ephemeris, clock correction and GNSS time reference with time for positioning can be as low as 1~2s.

Assumptions used by contributing companies in battery life analysis with NGSS position fix every UL transmissions:

* GNSS power consumption
  + Integrated GNSS and IoT module:
  + Separate GNSS module and IoT Module: Huawei, MediaTek (100 mW)
* GNSS Position Time To First Fix (TTFF)
  + Hot start: Huawei (1s or 2 s),
  + Warm start: Huawei (several seconds)
  + Cold start: Huawei (30 s)

In order to compare battery life analysis from contributing companies, we align their simulation results case by case based on assumption for reporting (2h and 6h), packet size (50 Bytes), GNSS position TTFF (2s and 5s), MCL = 154 dB assumption (this determines active time for Rx, Tx). This is to ensure there is convergence of methodology. The methodology included all transmissions and receptions in device in energy consumption models.

Separate GNSS module and IoT Module: Huawei, MediaTek (100 mW), CATT (216 mW)

For MediaTek and CATT simulation results we used scaling by 2 to provide figures from 1 day to 12 h to align with Huawei. Note that CATT used GNSS module power consumption of 216 mW; Huawei and MediaTek figures are shown with GNSS module power consumption of 100 mW. The results from companies show reasonable agreement and consistency in observations. At a medium MCL=154 dB, the battery life in NTN is in range 6 years to 16 years; the reduction in battery life is in range 10 % to 40 %.

|  |  |  |
| --- | --- | --- |
| GNSS TTFF (hot start 2s), 2h report | | |
| Source | Huawei  MCL=154 dB, 105 bytes UL, 320 ms report, GNSS 100 mW | MediaTek  MCL=154 dB, 50 bytes UL, 238 ms report, GNSS 100 mW |
| Total active IoT Rx time | 164 ms | 371 ms |
| Total active IoT Tx time | 534 ms | 335 ms |
| Battery life (TN) | 8.6 years | 10.5 years |
| Battery life (NTN) | 6.0 years | 6.9 years |
| Reduction in battery life | 30.2 % | 34.3 % |

|  |  |  |  |
| --- | --- | --- | --- |
| GNSS TTFF (warm start 5s), 12h report | | | |
| Source | Huawei  105 bytes UL, 320 ms report, GNSS 100 mW | MediaTek  50 bytes UL, 238 ms report, GNSS 100 mW | CATT  50 bytes UL, 320 ms report, **GNSS 216 mW** |
| Total active IoT Rx time | 164 ms | 371 ms | 641 ms |
| Total active IoT Tx time | 534 ms | 335 ms | 400 ms |
| Battery life (TN) | 24.3 years | 15.6 years | 15.6 years |
| Battery life (NTN) | 16.2 years | 11.9 years | 9.3 years |
| Reduction in battery life | 33.3% | 23.7 % | 40.4% |

Integrated GNSS and IoT module: Ericsson, MediaTek (37 mW):

Ericsson observed for eMTC/NB-IoT, the reduction in battery life can be up to around 6% at 164 dB MCL and up to around 17% at 144 dB MCL depending on the UL reporting interval, packet size, and RRC procedure. Similar observations can be made from ANNEX A in MediaTek contribution where the reduction in battery life can be around 2.6 % at 164 dB MCL and around 11.7% at 144 dB MCL with similar assumptions.

|  |  |  |
| --- | --- | --- |
| GNSS TTFF (hot start 1s), 2h report | | |
| Source | MediaTek  MCL=154 dB, 50 bytes UL, 238 ms report, GNSS 37 mW | Ericsson  MCL=154 dB, 50 bytes UL EDT, 238 ms report, GNSS 37 mW |
| Total active IoT Rx time | 371 ms | - |
| Total active IoT Tx time | 335 ms | - |
| Battery life (TN, years) | 10.5 years | 14.6 years |
| Battery life (NTN, years) | 9.5 years | 12.9 years |
| Reduction in battery life | 9.5 % | 11.6 % |

|  |  |  |
| --- | --- | --- |
| GNSS TTFF (warm start 5s), 24h report | | |
| Source | MediaTek  MCL=154 dB, 50 bytes UL, 238 ms report, GNSS 37 mW | Ericsson  MCL=154 dB, 50 bytes UL EDT, 238 ms report, GNSS 37 mW |
| Total active IoT Rx time | 371 ms | - |
| Total active IoT Tx time | 335 ms | - |
| Battery life (TN, years) | 31.2 years | 33.8 years |
| Battery life (NTN, years) | 27.9 years | 30.0 years |
| Reduction in battery life | 10.2 % | 11.2 % |

Power consumption—short, sporadic connections

Qualcomm considered case IoT UE transmit its payload once every hrs, once every hrs, etc; after transmitting the payload, the UE’s connection is released, and it goes back into deep sleep mode, until before the next transmission occasion. GNSS TTFF assumption is 2s. A typical NB-IoT over NTN scenario (e.g., a good coverage LEO satellite setting for Set 2) corresponding to a downlink SNR (for 15 kHz 1 PRB reception) of 0 dB and an uplink SNR (for 15 kHz 1 PRB transmission) of -5 dB (with a PC5 UE transmitting at the max. power of 20 dBm).



Figure 3: Short, sporadic transmissions for IoT over NTN.

**Under the studied scenario of short, sporadic connections, a GNSS fix before every connection consumes approximately of the UE’s total available energy.**

For UEs that are *mobile*, e.g., say tracking devices, etc., that are operating in this *short, sporadic connection* paradigm, this power penalty due to GNSS cannot be mitigated significantly, under the purview of Release 17 assumptions of GNSS-based uplink pre-compensation. However, for UEs that are *fixed*, e.g., smart meters, etc, these UEs may be able to save power by having a much more relaxed (e.g., once a week, or once a month, depending on the setting) GNSS fixing schedule.

Power consumption—long connections (e.g., based on CDRX)

Qualcomm considered case *long connection* according. The IoT UE may remain in connected mode for a significantly longer duration of time than the short, sporadic connections described above. These may be facilitated e.g., via connected mode DRX (CDRX), wherein much larger payloads are transmitted or received by the UE during the longer connection. 

Figure 4: Long connection with connected mode DRX for IoT over NTN.

A GNSS fix before every uplink transmission occasion (which, in the absence of other mechanisms, may end up being required to maintain uplink synchronization accuracy within specified limits) results in  **of the UE’s total power consumption resulting from GNSS fixes**. While we can mitigate this somewhat for fixed UEs, for mobile UEs (especially UEs moving at high speeds), without other enhancements to connected mode synchronization, we may not be able to avoid this hit to the UE’s power consumption on account of GNSS fixes.

**Under the studied scenario of a long connection employing connected mode DRX (with a DRX cycle of ), a GNSS fix before every uplink transmission consumes approximately of the UE’s total available energy without additional enhancements w.r.t uplink synchronization. This is especially true for mobile UEs that cannot depend on a prior acquired GNSS fix.**

Other observations from power consumption evaluation:

MediaTek observed a general trend with smallest battery life reduction in the order of 1% to 3% when battery life is in the order of 1 year; and largest battery life reduction in the order of 30% to 68% when battery life is in the order of 10 years or longer. GNSS TTFF hot start 1s, 2s and warm start 5s, 30s were simulated.

Ericsson observed that the reduction in battery life can be up to around 6% at 164 dB MCL and up to around 17% at 144 dB MCL depending on the UL reporting interval, packet size, and RRC procedure.

MediaTek observed that in scenarios of fixed IoT Sensors, or GNSS position available in Application Layer for Asset tracking / Fleet management, the impact on battery life is 0 %. There is either no need for UE to get a GNSS position fix (because the UE is fixed position with GNSS position acquired only once during fitting) or the GNSS position is available in the application layer because the UE needs to include it in the report.

CATT observed over 1 year battery life with transmission every 2hr of 200B, and over 2 years battery life with transmission every 2hr of 50B (on 216 mW), and over 10 years with transmission every day of 50B or 200B on 20mw GNSS power consumption of integrated architecture.

Nokia observed GNSS measurement may cause for packet size 50byte case, battery life reduction as 2.33% if 1s hot-start GNSS measurement assumed and 10.66% if 5s warm-start GNSS measurement assumed. While for 200bytes case, reduction will be 1.1% and 5.29% separately for hot-start and warm-start case. More battery life reduction when GNSS start is larger than 5s.

Ericsson proposed RAN1 to discuss and agree on the assumptions for IoT NTN battery life evaluation such as MCL, transmit power, bandwidth and noise figure.

CMCC, APT proposed the study of potential impact of GNSS Position fix on UE power consumption to be de-prioritized.

Moderator summary of power consumption simulations from contributing companies:

* *Contributing companies have shown consistent observations when using similar assumptions for reporting interval, packet size, GNSS TTFF and power consumption and MCL*
* *Impact on battery life is 0 % for use case fixed IoT sensors with GNSS position acquired once during fitting, or use case GNSS position available in IoT application Layer for Asset tracking / Fleet management*
* *In use case where the IoT device is not fixed position and GNSS position in not available in IoT application Layer, the following were observed based on contributing companies:*
  + *Reduction in battery life is around 6% at 164 dB MCL and around 17% at 144 dB MCL depending on the UL reporting interval, packet size, and RRC procedure with GNSS TTFF hot start 1s and warm start 5s and GNSS power consumption of 37 mW (integrated IoT and GNSS modules).*
  + *Reduction in battery life is around 1% to 3% when battery life is around 1 year; and 30% to 68% when battery life is around 10 years or longer with GNSS TTFF hot start 1s and warm start 5s and GNSS power consumption of 37 mW (integrated IoT and GNSS modules) and 100 mW (separate IoT and GNSS modules).*
  + *GNSS measurement may cause for packet size 50byte case, battery life reduction as 2.33% if 1s hot-start GNSS measurement assumed and 10.66% if 5s warm-start GNSS measurement assumed. While for 200bytes case, reduction will be 1.1% and 5.29% separately for hot-start and warm-start case. More battery life reduction when GNSS start is larger than 5s.*
  + *For short, sporadic connections, a GNSS fix before every connection consumes 34% of the UE’s total available energy; and in long connection employing connected mode DRX (with a DRX cycle of ~10s), a GNSS fix before every uplink transmission consumes 45% of the UE’s total available energy.*
  + *For long connection employing connected mode DRX (with a DRX cycle of ~10s), a GNSS fix before every uplink transmission consumes approximately 45% of the UE’s total available energy without additional enhancements w.r.t uplink synchronization.*
  + *Over 1 year battery life with transmission every 2hr of 200B, and over 2 years battery life with transmission every 2hr of 50B (on 216 mW), and over 10 years with transmission every day of 50B or 200B on 20mw GNSS power consumption of integrated architecture.*

*The battery life evaluation using in Rel-13 TR 45.820 (Section 5.4) has shown that overall the impact of GNSS can be moderate to significant, while allowing battery life of several years in case of significant reduction. The results would suggest that mitigation of power consumption due to GNSS could be a promising area of research that would be beneficial in case of high battery life comparable with cellular IoT of 10 years or beyond would be target for NTN IoT. The evaluation based on contributing companies would suggest the battery life in NTN IoT is sufficient for a working solution in worst case for power consumption where GNSS position fix is assumed to be needed before each UL transmission. In typical IoT applications, the impact on battery life would be 0 % for fixed IoT sensors or GNSS position available in Application Layer.*

***Initial proposal– Section 2.2:***

* ***Companies are encouraged to comment on IoT NTN battery life evaluation for the following:***
  + ***Assumptions for GNSS power consumption for integrated IoT and GNSS modules and separate IoT and GNSS modules***
  + ***Assumptions for report interval every 2h with GNSS TTFF hot start and every 6h, 12h, 24h with GNSS TTFF warm start***
  + ***Assumptions for MCL, transmit power, bandwidth and noise figure***
  + ***Moderator observations on convergence of contributing company evaluation results on battery life with similar assumptions.***
  + ***Moderator summary and whether it can be captured in TR 36.763 with contributing companies evaluation comparisons above and detailed evaluation with GNSS TTFF hot start 1s, 2s, and warm start 5s, 30s, GNSS power consumption for integrated IoT and GNSS modules 20 mW, 37 mW and for separate IoT and GNSS modules 100 mW, 216 mW, packet size 50 bytes, 105 bytes, 200 bytes, and report interval 2h, 6h, 12h, 24h in Appendix B.***

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| Company | Comments |
| GateHouse | Assumptions seem fine.  A note on alternative power consumption assumptions. Other potential assumptions are:   1. Aligning with 3GPP assumptions of power consumption during the development of EC-GSM/NBIoT. 2. Or use measured values on commercial devices like those reported in the paper [“An Empirical NB-IoT Power Consumption Model for Battery Lifetime Estimation”](https://vbn.aau.dk/ws/portalfiles/portal/279633819/vtcSpring2018.pdf) |
| ZTE | 1. For the power consumption for GNSS, it should be cover all typical implementation, e.g., 100 mw for separate module.  2. For hot start, 2s can be considered and 5 for warm start as baseline.  3. For the MCL, it’s up to the group on whether to check the worst case, e.g., MCL = 164 dB since according to system level simulation, the distribution for some UEs are close the limits. |
| Eutelsat | In general the assumptions seem acceptable. Regarding IOT Link Budget parameters, it is important to remember, at least for LEO, MCL is not a constant for any given user. The MCL presented in the link budget is a nominal ‘worst case’. However, MCL will vary with satellite position during a ‘fly-by’ and will differ on each orbit ‘fly-by’. In calculating power we should avoid ‘worst-case’ on ‘worst-case’ assumptions. See also 2.3.1. |
| Huawei， HiSilicon | We are in general fine with the summary and the intention to capture the evaluations results into the TR. One small comments on the wording below, I would assume it may be difficult to define “typical IoT application” for IoT. Maybe we can change it to “some IoT applications”.  *In ~~typical~~ some IoT applications, the impact on battery life would be 0 % for fixed IoT sensors or GNSS position available in Application Layer.* |
| Qualcomm | With the limited time we have, we propose a Section in the TR that documents the observations on GNSS power consumption results from different companies—under different situations (e.g., short connections, long connections, etc.).  The Section could state that GNSS-related power consumption was studied and have a broad sentence saying that the “ranges” of GNSS-related power consumption/battery-life reduction (e.g., ranging from X percent in Setting A from Company B, to Y percent in Setting C from Company D). The detailed analyses can be put into an appendix, as the FL has done here.  Why we propose this is:   1. We seem to all realize that GNSS does drain significant power, which isn’t really a contentious issue, we hope. 2. “Alignment” of numbers would take much more than the time-budget we have.   If we prioritize “short, sporadic connections” in Rel 17 WID, there isn’t really too much magic we can do to “prevent this power/battery life penalty”. |
| MediaTek | On 1, 37 mW for integrated, 100 mW for module  On 2, support assumption. Hot start can be 1 second, warm start 5 seconds  On 3) Link budget showed MCL can be as low as 164 dB. At such low MCL, the battery life is dominated by cellular IoT Rx and Tx active duration (many repetitions). The bandwidth and NF can lead to higher level of repetitions on UL and DL respectively.  We think battery analysis from companies can be documented in TR. |
| APT | Support to capture this battery analysis in TR. Agree with QC that only supporting intermittent delay-tolerant small packet transmission may prevent power penalty, e.g., short period in RRC\_CONNECTED. |
| Nokia, NSB | 1, For hot start, 1s and 2s should be considered as baseline. For warm start, 5s and larger value(s) should be considered as baseline. Considering the GNSS inaccuracy and unavailability issue, larger time consumption should also be considered or not excluded, to have an accurate analysis on power consumption closer to that in real world.  2, both middle coupling loss e.g. 154dB and large coupling loss e.g. 164dB should be considered in the calculation, to cover all the cases in real deployment.  3, to have a reasonable analysis, multiple packet size, report interval, hot/warm start time should be aligned and evaluated.  4, all evaluation results with different assumption should be added in TR |
| SONY | Broadly agree with the comments above. Specific points are:   * We agree with Eutelsat that the CL will change during a flypast, especially for LEO. Hence we do not need to consider the worst case MCL, but an average MCL across the flypast * We should be considering an MCL value that is consistent with what is considered in AI8.15.1. It seems like a max MCL of 154dB would be consistent with AI8.15.1, but we await conclusions from that AI   The moderator summary is good (thanks, moderator!). We should aim to capture this in TR36.763 at / after RAN1#105e. This will allow companies to further check the results or generate further results. The moderator summary is really useful in providing a list of those items that will be summarised in the TR. |
| Ericsson | We are open to discuss this further. |

### FIRST ROUND – GNSS Position fix impact on UE power consumption

GateHouse, ZTE, Eutelsat, Huawei, Qualcomm, MediaTek, APT, Nokia, SONY, Ericsson provided comments

Companies were encouraged to comment on IoT NTN battery life evaluation for the following:

* Assumptions for GNSS power consumption for integrated IoT and GNSS modules and separate IoT and GNSS modules
* Assumptions for report interval every 2h with GNSS TTFF hot start and every 6h, 12h, 24h with GNSS TTFF warm start
* Assumptions for MCL, transmit power, bandwidth and noise figure
* Moderator observations on convergence of contributing company evaluation results on battery life with similar assumptions.
* Moderator summary and whether it can be captured in TR 36.763 with contributing companies evaluation comparisons above and detailed evaluation with GNSS TTFF hot start 1s, 2s, and warm start 5s, 30s, GNSS power consumption for integrated IoT and GNSS modules 20 mW, 37 mW and for separate IoT and GNSS modules 100 mW, 216 mW, packet size 50 bytes, 105 bytes, 200 bytes, and report interval 2h, 6h, 12h, 24h in Appendix B.

Assumptions for GNSS power consumption for integrated IoT and GNSS modules and separate IoT and GNSS modules

* ZTE (100 mW), MediaTek (37 mW for integrated, 100 mW for module)

Assumptions for report interval every 2h with GNSS TTFF hot start and every 6h, 12h, 24h with GNSS TTFF warm start

* ZTE (hot start 2s, warm start 5s), MediaTek (hot start 1s, warm start 5s), Nokia (hot start 1s or 2s, warm start 5s, can be longer time)

Assumptions for MCL, transmit power, bandwidth and noise figure

* ZTE (worst case MCL=164 dB, can be discussed)
* Nokia (MCL 154 dB and 164 dB)
* MediaTek, SONY (a max MCL=154 dB would be consistent with 8.15.1),
* Eutelsat (worst case depends on satellite)

Moderator summary and whether it can be captured in TR 36.763 with contributing companies evaluation comparisons above and detailed evaluation with GNSS TTFF hot start 1s, 2s, and warm start 5s, 30s, GNSS power consumption for integrated IoT and GNSS modules 20 mW, 37 mW and for separate IoT and GNSS modules 100 mW, 216 mW, packet size 50 bytes, 105 bytes, 200 bytes, and report interval 2h, 6h, 12h, 24h in Appendix B.

* Huawei mentioned fine with summary, suggest revision “In ~~typical~~ some IoT applications, the impact on battery life would be 0 % for fixed IoT sensors or GNSS position available in Application Layer.”
* Qualcomm propose a Section in the TR that documents the observations on GNSS power consumption results from different companies—under different situations (e.g., short connections, long connections, etc.). The Section could state that GNSS-related power consumption was studied and have a broad sentence saying that the “ranges” of GNSS-related power consumption/battery-life reduction (e.g., ranging from X percent in Setting A from Company B, to Y percent in Setting C from Company D). The detailed analyses can be put into an appendix, as the FL has done here.
* Nokia commented to have a reasonable analysis, multiple packet size, report interval, hot/warm start time should be aligned and evaluated. All evaluation results with different assumption should be added in TR
* APT, SONY (at / after RAN1#105e) support to capture this battery analysis in TR.

Moderator view is consistent with Qualcomm further observation that GNSS drains significant power in case of “short, sporadic connections” with limited time for optimization in Rel 17 WID.

***First round proposal – Section 2.2.1:***

* ***Capture in TR 36.763, moderator’s summary GNSS Position fix impact on UE power consumption in Appendix A Section 5.1***

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## NTN SIB reading impact on UE power consumption

The following agreements were made in RAN1#104e

Agreement:

Study potential impact of NTN SIB carrying the satellite ephemeris on

* UE power consumption in NB-IoT and eMTC
* Accuracy of satellite location tracking
* PRACH congestion

### UE power consumption in NB-IoT and eMTC:

MediaTek used methodology based on TR 45.820, Section 5.4 to show the impact of SIB reading on battery life has max reduction of 1.61% with 16 bytes payload on NTN SIB. CATT observed the impact on battery life of NTN SIB1 reading to acquire satellite ephemeris for UE pre-compensation is negligible.

ZTE observed the power consumption of SIB reading for ephemeris Option 2 is significantly less than that of the Option 1. The power consumption of GNSS positioning is much larger than that of the SIB reading for ephemeris Option 2.

Ericsson proposed to accurately evaluate the impact of NTN SIB reads on eMTC/NB-IoT device battery life, RAN1 to discuss and agree on the assumptions for NTN SIB carrying satellite ephemeris such as NTN SIB format, periodicity and MCL.

Huawei observed decoding system information or receiving closed loop TAC command for TA adjustment during UL repetition will introduce extra power consumption for IoT devices

CMCC, APT proposed the study of potential impact of NTN SIB carrying the satellite ephemeris on UE power consumption to be de-prioritized.

The moderator view is that contributing companies have shown some impact on UE power consumption due to reading NTN SIB carrying the ephemeris. It is helpful as proposed by one company that RAN1 to discuss on the assumptions for NTN SIB carrying satellite ephemeris such as NTN SIB format, periodicity and MCL.

***Initial Proposal – Section 2.3.1:***

* ***Companies are encouraged to comment on the assumptions for reading NTN SIB carrying satellite ephemeris such as NTN SIB format, periodicity and MCL for* *UE power consumption***

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| Company | Comments |
| CATT | Based on our evaluation, the power consumption for reading SIB is negligible. |
| GateHouse | SIB periodicity and MCL will be dependent on the satellite constellation and operators use-case. Perhaps it would be more beneficial to focus on standardizing a SIB format (or more) and just provide guidelines on determining the required periodicity. |
| ZTE | The required power consumption for SIB reading is limited but for conducting the comprehensive study, the complexity and power consumption for DL synchronization on PSS/SSS is needed to be considered for initial stage. |
| Eutelsat | Agree with GateHouse regarding the focus of standardisation. See also our comment on MCL in LEO case in Section 2.2. |
| Huawei | The power consumption of SIB reading depends on the signalling payload of satellite ephemeris, SIB periodicity as well as the MCL. Based on our evaluation, the propagation error of orbital based ephemeris is small within tens of seconds and the overhead is 140bits. So the NTN SIB reading can be done before each report without a significant impact on power consumption. |
| Qualcomm | 1. Power consumption from reading SIB isn’t a limiting issue 2. For **short, sporadic connections**—the use case prioritized for Release 17—**there is no need for the UE to read the SIB in connected mode**; to facilitate this, we should **“implicitly limit” connection length by the notion of “ephemeris validity” at the UE**; if the UE deems ephemeris to be invalid, it should trigger RLF and re-establish from scratch. 3. For **long connections**—**a use case we** **strongly recommend we document in the TR**—more involved solutions may be considered and documented, including, potentially reading this SIB “sometimes” in CONNECTED mode, if the UE deems ephemeris tracking/propagation may become invalid, and a “non-RLF ephemeris-failure recovery procedure” (e.g., as proposed in Section 2.8.2) is more efficient. 4. NTN **SIB format should be discussed in the WID phase**, not in the study phase.   Based on the link budget numbers, **we don’t see any reason why this SIB would need any additional specification work in terms of coverage levels**, etc. |
| MediaTek | The power consumption due to SIB reading is very small assuming worst case where it is done before each report (i.e. in the order of 1% reduction in battery life) |
| APT | Share the same view as QC. No SIB reading in RRC\_CONNECTED. As result, no GNSS update in RRC\_CONNECTED for NB-IoT. |
| Nokia, NSB | For SIB format, period of ephemeris, I think firstly we need to wait for progress of format for NR NTN. Then the supported coupling loss and power consumption could be studied. |
| SONY | Tend to agree with Nokia. However, since this is a study, maybe it is OK to make some assumptions such as:   * NTN-SIB overhead is 140 bits (from Huawei) * NTN-SIB periodicity is 1 second. The periodicity needs to be a fraction of the time that a beam / cell can be active and for LEO-600, the UE can be within the beam of a satellite for under 7 seconds. Hence a periodicity of around 1 second seems reasonable * 154dB MCL (as for GNSS measurement study) |
| Ericsson | Further discussions are needed to agree on the assumptions for NTN SIB carrying satellite ephemeris such as NTN SIB format, periodicity and MCL. |
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#### FIRST ROUND -UE power consumption in NB-IoT and eMTC:

CATT, GateHouse, ZTE, Eutelsat, Huawei, Qualcomm, MediaTek, APT, Nokia, SONY, Ericsson provided comments

Companies were encouraged to comment on the assumptions for reading NTN SIB carrying satellite ephemeris such as NTN SIB format, periodicity and MCL for UE power consumption

* CATT, ZTE, Huawei, MediaTek, Qualcomm commented the required power consumption for SIB reading is not significant
* Qualcomm commented for short, sporadic connections—the use case prioritized for Release 17—there is no need for the UE to read the SIB in connected mode. 3. For long connections—more involved solutions may be considered and documented in TR. NTN SIB format should be discussed in the WID phase. SIB would not need any additional specification work in terms of coverage levels based on the link budget numbers.
* APT commented no SIB reading in RRC\_CONNECTED, no GNSS update in RRC\_CONNECTED for NB-IoT.
* Nokia, Ericsson commented for SIB format, period of ephemeris, wait for progress in NR NTN first.
* SONY commented that NTN-SIB overhead is 140 bits (from Huawei), NTN-SIB periodicity is 1 second. The periodicity needs to be a fraction of the time that a beam / cell can be active and for LEO-600, the UE can be within the beam of a satellite for under 7 seconds. 154dB MCL (as for GNSS measurement study)

Moderator view is that based on the comments and evaluation, the required power consumption for SIB reading is not significant for short sporadic connections use case prioritized in Rel-17. For long connections, more involved solutions can be discussed in Section 2.3.2

***First round proposal – Section 2.3.1.1:***

***Conclusion***

* ***The required power consumption for SIB reading is not significant for short sporadic connections use case prioritized in Rel-17.***

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| Company | Comments |
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### Accuracy of satellite location tracking:

Qualcomm made the following observations and proposals:

* If a half-duplex UE (i.e., all NB-IoT and some eMTC UEs) is mandated to read the SIB (containing satellite location information) immediately preceding every uplink transmission, this may lead to dropped uplink transmissions. At least for short, sporadic connections, a SIB containing satellite location information is not read in connected mode.
* An implicit way to limit connection length for eMTC/NB-IoT over NTN is via the definition of synchronization validity.RAN1 to define the notion of synchronization validity during which the ephemeris and/or GNSS information is (are) accurate. This validity is based on timer(s) that are (re-)set autonomously by the UE after acquiring necessary location information. Such (re-)setting events may be indicated to the network to facilitate efficient scheduling.
* RAN1 to introduce a mechanism that triggers RLF when the GNSS and/or ephemeris information at the UE is (are) outdated:

MediaTek observed that the UE only needs to acquire SIB1 once within System Information update periodicity to know the scheduling of NTN-specific SIB carrying the serving satellite ephemeris position and velocity state vector.

The moderator view is that more discussion is needed g and would encourage companies to comment to check understanding.

***Initial Proposal – Section 2.3.2:***

* ***Companies are encouraged to comment on accuracy of satellite location tracking for the following:***
  + ***SIB containing satellite location information is not read in connected mode for short sporadic connections***
  + ***Validity during which the ephemeris and/or GNSS information is (are) accurate based on timer set/reset autonomously by the UE***
  + ***Mechanism to trigger RLF when the GNSS and/or ephemeris information at the UE is outdated***

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| Company | Comments |
| CATT | If suitable predication method is applied, UE is not needed to read the SIB to get the satellite location frequently. |
| GateHouse | On a related note, we have suggested two types of ephemeris data:   1. One that is accurate and valid for a short period, which is used to synchronize to the PUSCH. 2. Another that is less accurate, but valid for a long period and used for scheduling of power save mode and/or discontinuous reception. |
| ZTE | Whether to tracking the satellite location via additional reading of SIB is up to the valid duration for each configuration.  In case that the associated timer for satellite location is expired, the UE need to re-read the SIB. |
| Xiaomi | Prediction method should be discussed before discussing the periodicity of SIB reading. |
| Eutelsat | Agree with the moderator. Qualcomm’s points summarised above should be taken into consideration. Triggering Radio Link Failure (RLF) on outdated information is interesting (may need to be considered by RAN2 (\*)) as it would seem to permit a wider range of implementations than a fixed timer.  (\*) Presently we understand, according to TS 36.331, the network may trigger connection release for connected mode UE. |
| Huawei | 1. The satellite position can be predicted with acceptable accuracy within tens of seconds, hence there is no strong need to read SIB containing satellite location information in connected mode as long as the connection time does not last longer than that. However, this may depends on the traffic characteristics including packet arrival rate. 2. We are not fully convinced about the need to introduce a validity timer within which the ephemeris and/or GNSS information can be assumed to be accurate. As commented in section 2.1, how frequency the UE needs to perform GNSS measurement depends on both scenarios and UE implementations. It is difficult for the gNB to configure a validity timer without any information from the UE. 3. This relates to the second bullet and we are not sure whether there is a need to discussed in RAN1 |
| CMCC | Regarding the first bullet, if satellite location information can be **frequently updated** by network, and change of satellite location information field in SIBx should neither result in system information change notifications nor in a modification of valueTag in SIB1, just like ***timeInfoUTC*** field in SIB9, it seems no need to read SIB containing satellite location information in connected mode seems for short sporadic connections.  Regarding the second and third bullet, if satellite location information can be **frequently updated** by network, UE can obtain the latest ephemeris information in initial access, hence ephemeris information outdating at the UE may be avoided for short sporadic connections. |
| Qualcomm | 1. As we described before, for “short, sporadic connections”—prioritized in Release 17—there is **no need to read SIB (including the SIB carrying ephemeris) in connected mode.** 2. **In the spirit of “short connections”**, however, we would like to point out that **this “restriction” has to be specified in some form**, for the system to **work simply** *without needing the elaborate changes that are required for longer connections*. Current specifications—to the best of our knowledge—don’t restrict connection length in any direct form.   **To achieve this “restriction” to short connections, we need to define the notion of synchronization validity and synchronization expiry at the UE**.  When the UE gets a GNSS fix and/or an ephemeris fix, it can consider itself to be “in valid uplink sync” for a certain duration of time. When these duration(s) expire, everything starts from scratch.  The durations of these times should be further discussed (e.g., satellite providers have previously provided numbers showing that gravity-based satellite location-tracking can be reasonably accurate up to ~10s of seconds). The durations—for GNSS—may depend on the UE’s speed too; for example, for a fixed UE, the GNSS validity can be infinite, while for a UE moving at 120 kmph, this may be ~10 seconds. **We should work on the details of this in the WID phase, but the *functionality in and of itself is strictly essential for Rel 17*.** |
| MediaTek | We think no need to read SIB containing satellite location information in connected mode for short sporadic connections. This assumes the UE is not kept in connected for a long time (e.g. 10 seconds or so)  We have similar views as Huawei and CMCC on validity timer. This should be discussed in RAN2 first. Same view on third bullet. |
| APT | Q1: support no SIB reading in RRC\_CONNECTED  Q2: no validity timers for GNSS and ephemeris since no SIB reading and GNSS updates in RRC\_CONNETED  Q3: no enhancement on RLF as pointed out in RAN#91. |
| Nokia, NSB | We agree there are several sources for GNSS or ephemeris outdate or unavailable, and validity of GNSS/ephemeris and solutions if not valid any more should be studied. We also agree a timer based validity could be a simple way to guarantee an aligned understanding between UE and eNB on validity of sync.  While for activity when outdated, it should be FFS, for the sync failure related action, e.g. similar action as to stop the ongoing transmission, action to re-sync in UL, etc. |
| SONY | Q1: no need to read SIB in RRC\_CONNECTED  Q2/3: These issues should be further studied |
| Ericsson | * First bullet: Whether reading SIB containing satellite ephemeris will be needed in connected mode depends on time/frequency accuracy requirements that are not yet defined. * Second bullet: Is the meaning of “autonomously” that the UE determines the timer value? Then this would be an internal matter to the UE that need not be specified. But the UE needs to meet accuracy requirements for time/frequency compensation.   Third bullet: We don’t see that this is necessary. |

#### FIRST ROUND - 2.3.2 Accuracy of satellite location tracking:

CATT, GateHouse, ZTE, Xiaomi, Eutelsat, Huawei, CMCC, Qualcomm, MediaTek, APT, Nokia, SONY, Ericsson provided comments

Companies were encouraged to comment on accuracy of satellite location tracking for the following:

SIB containing satellite location information is not read in connected mode for short sporadic connections

* CATT, Xiaomi, Ericsson Huawei, MediaTek commented whether it is needed to read SIB containing satellite ephemeris in CONNECTED depends on prediction method, time/frequency accuracy requirements (over 10s of seconds)
* ZTE commented whether to tracking the satellite location via additional reading of SIB is up to the valid duration for each configuration.
* Qualcomm, MediaTek, CMCC commented for “short, sporadic connections”—prioritized in Release 17—there is no need to read SIB (including the SIB carrying ephemeris) in connected mode. Qualcomm commented in the spirit of “short connections”, however, we would like to point out that this “restriction” has to be specified in some form, for the system to work simply without needing the elaborate changes that are required for longer connections. Current specifications don’t restrict connection length in any direct form. Qualcomm commented further that this depends on whether satellite location information can be frequently updated by network, and change of satellite location information field in SIBx should neither result in system information change notifications nor in a modification of valueTag in SIB1.
* SONY, APT commented no need to read SIB in RRC\_CONNECTED

Validity during which the ephemeris and/or GNSS information is (are) accurate based on timer set/reset autonomously by the UE

* ZTE commented in case that the associated timer for satellite location is expired, the UE need to re-read the SIB.
* Huawei commented on whether there is a need to introduce a validity timer, UE needs to perform GNSS measurement depends on both scenarios and UE implementations. It is difficult for the gNB to configure a validity timer without any information from the UE
* MediaTek commented validity timer can be first discussed in RAN2
* Qualcomm commented when the UE gets a GNSS fix and/or an ephemeris fix, it can consider itself to be “in valid uplink sync” for a certain duration of time. When these duration(s) expire, everything starts from scratch.
* APT commented no validity timers for GNSS and ephemeris since no SIB reading and GNSS updates in RRC\_CONNETED
* Nokia commented on GNSS or ephemeris outdate or unavailable, and validity of GNSS/ephemeris and solutions such as validity timer should be studied.
* Ericsson commented on the meaning of “autonomously” for UE determination of the timer value, which would then not need to be specified

Mechanism to trigger RLF when the GNSS and/or ephemeris information at the UE is outdated

* Eutelsat interested in triggering Radio Link Failure (RLF) on outdated information
* Huawei commented similarly as validity of ephemeris and/or GNSS information, whether there is a need to discuss in RAN1
* CMCC commented when the UE gets a GNSS fix and/or an ephemeris fix, it can consider itself to be “in valid uplink sync” for a certain duration of time. When these duration(s) expire, everything starts from scratch.The durations of these times should be further discussed (e.g., satellite providers have previously provided numbers showing that gravity-based satellite location-tracking can be reasonably accurate up to ~10s of seconds). The durations—for GNSS—may depend on the UE’s speed too; for example, for a fixed UE, the GNSS validity can be infinite, while for a UE moving at 120 kmph, this may be ~10 seconds. We should work on the details of this in the WID phase, but the functionality in and of itself is strictly essential for Rel 17.
* MediaTek commented trigger mechanisms can be first discussed in RAN2.
* APT commented no enhancement on RLF as pointed out in RAN#91

Moderator view is that based on company comments, there seems to be shared understanding that UE does not need to read SIB containing satellite location information in connected mode for short sporadic connections. The UE can read SIB before moving to connected, predict amount of UE pre-compensation for UL transmission accurately over 10s of seconds, then moved to connected. The details and impact on specifications should be kept simple and can be left to normative phase. The system should work simply without needing the elaborate changes that are required for longer connections.

***First round proposal – Section 2.3.2.1:***

***Conclusion***

* ***The UE does not need to read SIB containing satellite location information for short sporadic connections use case prioritized in Rel-17***

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| Company | Comments |
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### PRACH Congestion:

Sony proposed RAN1 studies ways of mitigating PRACH congestion when IDLE mode UEs simultaneously transmit PRACH after receiving satellite PVD information. The PRACH congestion is illustrated in figure below. Once the UEs have the satellite PVD information, all the UEs attempt to transmit at the same time, leading to a spike in PRACH activity and PRACH congestion. One solution is that UEs defer transmission of their PRACH following reception of SIB carrying satellite PVD information by a random amount, such that PRACHs arrive in a uniformly distributed fashion between SIB transmissions. Other way is UEs spread out the times at which they transmit PRACH when satellite is not shadowed to spread out the PRACH load in time.



Ericsson propose RAN1 to discuss and agree on the underlying scenario to study the impact of NTN SIB on PRACH congestion.

OPPO propose PRACH transmission back-off can be beneficial to resolve the issue of PRACH congestion.

CATT observed a large amount of UEs are linked to same PRACH occasion after reading SIB1, which probably causes PRACH congestion.

MediaTek proposed that to avoid RACH congestion, NTN SIB carrying the ephemeris for the UE prediction and pre-compensation of satellite delay and Doppler shift is broadcast with a low periodicity – e.g. 1 second.

CMCC proposed there is no PRACH congestion problem with SIB read.

The moderator view is that more discussion is needed to check understanding on scenario to study the impact of NTN SIB on PRACH congestion.

***Initial Proposal – Section 2.3.3:***

* ***Companies are encouraged to comment on scenario to study the impact of NTN SIB on PRACH congestion***

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| Company | Comments |
| CATT | Based on current IoT specification, RACH congestion is unavoidable since RACH resources are linked to SIB transmission. So this issue should be studied and related solution is needed. |
| GateHouse | One way to circumvent this issue of correlated access is to introduce a random delay after the last SIB before a UE attempts random access. |
| ZTE | It’s preferred to study the PRACH congestion with well evaluation. We can further consider to enhance the PRACH capacity if this issue is serious. |
| Eutelsat | We would agree RACH congestion is a potential issue which should be studied and, if it poses a practical limitation, solutions/ mitigations should be captured in the TR and/or handled at application level. |
| Huawei | In current specification, the period of PRAH is configurable by the eNB. With a smaller PRACH period, PRACH congestion can be alleviated. However, we are open to discuss under which circumstance, e.g. user density, RACH periodicity, SIB periodicity, etc., the issue become serious. |
| CMCC | For DRX operation, PRACH congestion issue may be avoid by network implementation with aligned configuration of DRX and SIB containing satellite location information.    Nevertheless, for UE with sporadic UL traffic, PRACH congestion seems to be a potential issue which needs further study. |
| Qualcomm | While we think that with sufficiently frequent transmissions of the ephemeris-carrying SIB, (together with the notion of ephemeris validity described in Section 2.3.2 above), PRACH congestion may not be a huge bottleneck, *we do acknowledge the points raised by the companies*. Some example situations (comprising, some example SIB periodicities, ephemeris validity durations, UE traffic pattern, etc.) *may benefit from some solutions proposed here*—such as *introduction of a random delay after reading the ephemeris SIB (the random delay being within the ephemeris validity period)*.  We are open to investigate this on our end too, and at a minimum, support documenting the observations and solutions in the TR.  We can potentially down-scope to a simple solution for Release 17, either in the next meeting, or among different candidate options in the WID phase itself. |
| MediaTek | PRACH congestion can be avoided buy network implementation to our understanding. It is fine to discuss further. |
| APT | NW could handle this by Backoff Indicator (BI).  [3GPP TS 36.321 V16.4.0] if in this Random-Access procedure, the Random-Access Preamble was selected by MAC: based on the backoff parameter, select a random backoff time according to a uniform distribution between 0 and the Backoff Parameter Value.  Also, we share ZTE’s view. As shown in R2-2104033, RAN2 expected RAN1could study PRACH capacity. |
| Nokia, NSB | As there is no consensus on whether there will be PRACH congestion, it should be firstly studied/evaluated whether there will be congestion considering different scenarios, connection density, PRACH capacity, etc. |
| SONY | We think that PRACH congestion will occur under conditions of high user density and when SIB update periodicity is long relative to the RO periodicity.  Increasing the frequency of ROs does not improve the situation. The ROs that are close to the SIB carrying satellite ephemeris / position-velocity-drift (PVD) information will end up being congested and the other ROs will be lightly used.  Transmission of PRACH at a random time after SIB transmission would be one way to alleviate this issue. We are open to consider other potential solutions and these potential solutions can be described in the TR. For example, the UE could transmit PRACH at a time after SIB when the channel conditions are known to be good (since different UEs have obstructed views of the sky at different times, the times at which UEs transmit PRACH should end up being spread out).  In order to evaluate this issue, we could use similar assumptions to other studies:   * SIB containing ephemeris / PVD info transmitted every [1] or [10] seconds * Frequent ROs * SIB info contains 140 bits * MCL = 154dB   We are open to consider other parameters or to document results in a contribution-driven manner. |
| Ericsson | We agree that scenarios should be agreed on before studying the impact of PRACH congestion. |

#### FIRST ROUND – PRACH Congestion

CATT, GateHouse, ZTE, Eutelsat, Huawei, CMCC, Qualcomm, MediaTek, APT, Nokia, SONY, Ericsson provided comments

Companies are encouraged to comment on scenario to study the impact of NTN SIB on PRACH congestion

* ZTE, CATT (unavoidable issue since RACH resources are linked to SIB transmission),
* Qualcomm, Gatehouse, APT, SONY (introduce a random delay after the last SIB before a UE attempts random access)
* Companies commented it can be avoided via configuration: Huawei (smaller PRACH period), CMCC (aligned configuration of DRX and SIB containing satellite location information), MediaTek (network configuration)
* Nokia commented it should be first studied/evaluated whether there will be congestion considering different scenarios, connection density, PRACH capacity, etc.
* SONY proposed SIB containing ephemeris / PVD info transmitted every [1] or [10] seconds, Frequent ROs, SIB info contains 140 bits, MCL = 154dB

Moderator view is that there is some understanding and no consensus from commenting companies that this PRACH congestion is an issue that needs to be discussed further. There seems to be several ways this issue could be handled. We support Qualcomm proposal to potentially down-scope to a simple solution for Release 17, either in the next meeting, or among different candidate options in the WID phase itself.

***First round FL recommendation – Section 2.3.3.1:***

***Proponents of PRACH congestion issue are encouraged to provide some analysis on scenarios and consider whether network configuration can mitigate issue of PRACH congestion.***

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| Company | Comments |
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## Long UL transmission on PUSH

The following agreements were made in RAN1#104e

Agreement:

Study the UE pre-compensation of satellite delay during long UL transmission on (N)PUSCH in NB-IoT and eMTC.

Agreement:

Study the UE pre-compensation of satellite Doppler shift during long UL transmission on (N)PUSCH in NB-IoT and eMTC.

In extreme coverage MCL > 164 dB, the maximum PUSCH transmission can be max RU length x max number of RUs per TBS x max number repetitions. For 1 RB transmission, it is (1 ms x 1) x 10 x 128 = 1.28 s; for single tone transmission with 15 kHz, it is (1 ms x 16 x 0.5) x 10 x 128 = 10.24 s; for single tone transmission with 3.75 kHz, it can be as long as (4 ms x 16 x 0.5) x 10 x 128 = 40.96 s. Assuming a delay drift rate of up to 20 us/s and a Doppler shift drift rate of up 640 Hz/s, the delay and Doppler shift can vary by as much as 819 us and 26.2 kHz respectively. This would break the cyclic prefix and ICI, resulting in loss of orthogonality of OFDM waveform. Rel-13 specified a UL Compensation Gap (UCG) of 40 ms that is inserted every 256 ms to allow Half-Duplex UE to re-sync on DL. The UCG can also be used if it is needed to re-acquire satellite ephemeris on NTN SIB to re-calculate the amount of UE pre-compensation for delay and Doppler shift to apply during the long PUSCH transmission. In the NB-IoT specification 36.211, the NPUSCH UL Compensation Gap (UCG) definition is given as

*After transmissions and/or postponements due to NPRACH of time units, a gap of time units shall be inserted where the NPUSCH transmission is postponed. The portion of a postponement due to NPRACH which coincides with a gap is counted as part of the gap*.

When 2 HARQ processes are configured, the total maximum duration of both NPUSCH transmissions is not more than 256 ms, and any scheduling gap between the two NPUSCHs counts as part of the 256 ms



The maximum duration of PUSCH transmission exceeding 256 ms is not an issue for UL synchronization since there is a UCG of 40 ms every 256 ms. Up to 40.96 s transmission of PUSCH mentioned by contributing companies seems too high level of repetitions:

* Rel-13 TR 45.820 mentions that M2M device delay requirement of 10 seconds for maximum latency is appropriate for the uplink when measured from the application 'trigger event' to the packet being ready for transmission from the base station towards the core network.
* A UE will typically be kept in connected for 10 seconds or lower for intermittent delay-tolerant small packet transmissions.
* Though the maximum transmission time 40.96s is allowed in the cellular IoT specifications, it is a maximum theoretical time that is not used in practical cellular IoT systems.
* A longer transmission time of up to 40.96 seconds mean that the UE cannot complete packet transmission assuming satellite beam dwell time as small as 10 seconds.
* In NB-IoT deep coverage / eMTC Coverage mode A at MCL=154 dB, a transmission time of 250 hundred ms for the long PUSCH assuming a 50B packet is adequate (this allows transmission of a packet at SNR as low as -10 dB).
* In NB-IoT extreme coverage / eMTC Coverage mode B at MCL=164 dB, a transmission time of 1.5 second for the long PUSCH assuming a 50 Bytes is adequate (this allows transmission of a packet at SNR as low as -20 dB).

Pre-compensation in long PUSCH repetition re-using legacy UCG:

Ericsson, OPPO, Intel, Apple, Samsung, Sony, MediaTek observed whether there is need for specification change / new gap to allow the UE to perform UL pre-compensation during a long UL transmission. UE may pre-calculate the timing and frequency pre-compensation values for each anticipated pre-compensation occasion prior to the start of the UL transmission.

Qualcomm proposed UE-triggered scheduling gap due to stale satellite location information (and not due to a stale GNSS fix)..

To the moderator understanding, companies not supportive of new gaps assumed that UE pre-compensation is done slot-by-slot or over a number of slots during the repetitions over a maximum of 256 ms.

Segmented pre-compensation in long PUSCH repetition with new gap:

Huawei, ZTE, CATT, Spreadtrum, APT supported new gap during long PUSCH transmission.

Sony propose the UE updates the timing of its PUSCH transmissions every ‘N’ ms, where ‘N’ is either 8 or 16ms to be low enough to allow for the maximum rate of change of timing misalignment and should also be high enough to allow the eNB to perform cross-subframe channel estimation and / or symbol combining.

ZTE proposed segmented pre-compensation for long continuous repetition transmission, where different segments generally apply different pre-compensation values. A gap is inserted between adjacent segments to avoid the overlap of segments caused by different TA pre-compensation. The gap can also be used to update ephemeris (e.g., satellite PV value) or other synchronization related indication for accurate TA/Doppler compensation. How to set the time length of inserted gap should be further investigated



To the moderator understanding, companies supportive of the gap assumed that UE pre-compensation is not done slot-by-slot during the repetitions. During the gap, the UE determines the UE pre-compensation for a segment and applies it to the long PUSCH transmission in same way for each of the repetitions until the next gap. This means more frequent gaps than every 256 ms need to be inserted due to the variation in delay and Doppler shift.

TA drift used for UE pre-compensation in long PUSCH transmission:

Xiaomi, Samsung propose to use TA drift rate for UE pre-compensation of TA in long PUSCH transmission.

Sony, Lenovo, Intel proposed the TA drift rate of feeder link is broadcast and used by the UE for TA adjustment.

The moderator view is that TA drift rate over the feeder link in case reference point for DL-UL subframe timing alignment is at the NB is on-going discussion in NR NTN WI and we can postpone discussions in IoT NTN SI. On the TA drift rate over the service link, it can be first discussed how the pre-compensation is applied within 256 ms and whether new gaps are needed for the long PUSCH transmission.

Based on the moderator understanding, more discussions is needed to check understanding of the issues with long PUSCH transmissions and how the UE pre-compensation could be determined and applied by the UE. The UE pre-compensation can be applied to satellite delay and Doppler shift.

***Initial Proposal – Section 2.4:***

***Companies are encouraged to comment on ways UE can apply the pre-compensation of delay and Doppler shift during long PUSCH transmission:***

* ***Q1: Is it company understanding that UE pre-compensation can be applied at least once every 256 ms during specified UCG in case of long PUSCH transmission greater than 256 ms.***
* ***Q2: In case UE pre-compensation is done slot-by-slot / over a number of slots N in long PUSCH repetitions re-using legacy UCG***
  + ***What is the value of N – i.e. 1, 8, 16***
  + ***Can feasibility of this method be up to UE implementation?***
* ***Q3: In case of segmented pre-compensation in long PUSCH repetitions with new gaps***
  + ***What is the assumption for maximum variation of delay and Doppler shift for segmented pre-compensation?***
  + ***What is the new gap periodicity and duration?***

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| Company | Comments |
| CATT | * ***Q1: Is it company understanding that UE pre-compensation can be applied at least once every 256 ms during specified UCG in case of long PUSCH transmission greater than 256 ms.***   Answer: Pre-compensation period could be shorter than 256ms.   * ***Q2: In case UE pre-compensation is done slot-by-slot / over a number of slots N in long PUSCH repetitions re-using legacy UCG***   + ***What is the value of N – i.e. 1, 8, 16***   Answer: can be determined later.   * + ***Can feasibility of this method be up to UE implementation?***   Answer: could be pre-configured   * ***Q3: In case of segmented pre-compensation in long PUSCH repetitions with new gaps***   + ***What is the assumption for maximum variation of delay and Doppler shift for segmented pre-compensation?***   Answer：For delay, it can be less than 1/2 CP. For Doppler shift, it could be less than 1khz.   * + ***What is the new gap periodicity and duration?***   Answer: depending on tolerable timing and frequency shift. |
| GateHouse | Q1: Yes  Q2: The 40 ms gap period for cooling down (UCG) should be sufficient to receive SIB and adjust the compensation of delay and doppler offset. We suggest letting the exact method be up to UE implementation.  Q3: Q3 is not clear. If the reference is to transmissions that are “interrupted” by RACH then the above still applies except there is more time to obtain a new SIB and synchronize. |
| ZTE | Q1: The legacy UCG with 40 ms is defined to re-sync the DL and there is no additional behaviour is required for UL synchronization before the transmission (i.e., same TA adjustment is assumed). For reusing this mechanism for sync, the duration may needed to be extended to handle the impacts on the updates of satellite location. For example, before the UL transmission, the satellite information is obtained, but it’s expired during long PUSCH transmission since the later one can be up to seconds.  Q2: It’s prefer to define the explicit time range for the usage of one TA. Otherwise, there will be mismatch between UE and gNB on the reception (including potential collision between different components). W.r.t the value N, it can be further determined once the typical scenarios is agreed.  Q3: As the baseline, the maximum variation for delay should be within CP. For the Doppler shift, it’s up to the configuration of PUSCH transmission.  The detailed parameters for gap can be discussed in normative phase. |
| Xiaomi | Q1: yes  Q2: 1) The value of N can be determined later.  2) It should be pre-configured.  Q3: It depends on tolerable timing and frequency shift. |
| Eutelsat | No strong opinion on the specific questions. We support the moderator comment to further discuss solutions to enable longer PUSCH transmissions. |
| Huawei | * ***Q1: Is it company understanding that UE pre-compensation can be applied at least once every 256 ms during specified UCG in case of long PUSCH transmission greater than 256 ms.***   The timing drift caused by the movement of satellite at smaller elevation during 256ms will be much large than the timing requirement, so the 256ms time continuous transmission may be too long for IoT NTN.   * ***Q2: In case UE pre-compensation is done slot-by-slot / over a number of slots N in long PUSCH repetitions re-using legacy UCG***   + ***What is the value of N – i.e. 1, 8, 16***   + ***Can feasibility of this method be up to UE implementation?*** * ***Q3: In case of segmented pre-compensation in long PUSCH repetitions with new gaps***   + ***What is the assumption for maximum variation of delay and Doppler shift for segmented pre-compensation?***   + ***What is the new gap periodicity and duration?***   For Q2, even UE pre-compensation is done slot-by-slot / over a number of slots new gaps are still needed for TA adjustment. We think it is crucial to ensure the common understanding on the number of slots as well as the new gaps between the UE and gNB.  For Q3, For IoT NTN, the maximum time continuous transmission for UL should not be a fixed values as the variation of delay and Doppler shift is related to the elevation and satellite velocity. The new gap can be configured by the eNB, e.g. indicated in the cell specific information according to the minimum elevation of the cell. |
| CMCC | Q1: yes.  Q2: If UE know the TA drift, why not adjust its UL transmission frequency (i.e., in symbol-by-symbol level)? Which is beneficial for the eNB to perform channel estimation. Otherwise, if UE doesn’t know the TA drift, UE cannot do the pre-compensation no matter done slot-by-slot or over a number of slots N.  Q3: The functionality of new GAP needs more clarification. It is used for DL re-synchronization, MAC CE TA command receiving, or SIB read for updated satellite position? |
| Apple | Q1: In case of long PUSCH transmission greater than 256 ms, the UE pre-compensation should be applied at least once every X ms, where X should be less than 256 considering the moving satellite.  Q2: The value of N may depend on scenario (e.g., larger value for GEO and smaller value for LEO).  Q3: Maximum variation of delay of 20 us/s is used to calculate the segmented pre-compensation in long PUSCH repetitions. Overall, the gap periodicity and duration may depend on the scenario (e.g., GEO vs. LEO) and satellite ephemeris. |
| Qualcomm | * ***Q1: Is it company understanding that UE pre-compensation can be applied at least once every 256 ms during specified UCG in case of long PUSCH transmission greater than 256 ms.***   UE pre-compensation—to our understanding—**must be done during the transmission, like what is proposed in Q2**. We cannot use the same pre-compensation values (without any shorter-term changes, e.g., based on the drift, etc.) for something as long as 256 ms, in NTN.  We think **issues have gotten mixed up here**. The 256 ms duration exists today just so that the **UE can re-sync with the downlink in the next 40 ms**. It has **nothing to do with any “pre-compensation”**, since that notion doesn’t exist in terrestrial networks.  So, the “answer” to this question is no, but the **“solution” isn’t “gaps”**—the **solution is what is proposed in Q2.**   * ***Q2: In case UE pre-compensation is done slot-by-slot / over a number of slots N in long PUSCH repetitions re-using legacy UCG***   + ***What is the value of N – i.e. 1, 8, 16***   + ***Can feasibility of this method be up to UE implementation?***   **This should be the baseline for uplink transmissions in NTN. We should figure out the details—e.g., value of N, etc.—in the WID phase.**   * ***Q3: In case of segmented pre-compensation in long PUSCH repetitions with new gaps***   + ***What is the assumption for maximum variation of delay and Doppler shift for segmented pre-compensation?***   + ***What is the new gap periodicity and duration?***   We **don’t see the use-case for “segmented transmission” due to delay and/or doppler pre-compensation**. To re-iterate the point made under Q1 above, the **current segmented transmission of 256 ms followed by 40 ms gap has nothing to do with pre-compensation**.  With how long a typical ephemeris is valid (with tracking algorithms and continuous adjustments, as described in Q2), and for almost all reasonable UE speeds, we think **all uplink transmissions can be covered within the space of solutions in Q2 above**. For the extreme corner cases (e.g., the worst coverage possible, with the highest speeds possible), we should simply have the UE declare RLF if its synchronization timers for ephemeris and/or GNSS fail (as described in Section 2.3.2) |
| Spreadtrum | Q1: The period and duration of UCG may needed to be enhanced.  Q2: 1) The value of N can be determined later.  2) Pre-configured.  Q3: It depends on tolerable timing and frequency shift. The detailed parameters for gap can be discussed in normative phase. |
| APT | Q1: yes  Q2: N = 1, or up to UE implementation. However, we have a concern about overlapping. When an overlap happens due to timing adjustment, the later overlapped part will be dropped in this release. The spec text is given below.  *[3GPP TS 36.213 V16.5.0] For serving cells in the same TAG, when the UE's uplink PUCCH/PUSCH/SRS transmissions in subframe n and subframe n+1 are overlapped due to the timing adjustment, the UE shall complete transmission of subframe n and not transmit the overlapped part of subframe n+1.*  Q3: if a new UCG is needed rather than 40ms per 256ms, then the new UCG can be controlled by NW to fit different NTN scenarios, e.g., LEO, MEO, GEO, fixed UE, and mounted UE. |
| MediaTek | ***Q1: Is it company understanding that UE pre-compensation can be applied at least once every 256 ms during specified UCG in case of long PUSCH transmission greater than 256 ms.***  Q1: Yes. Question Q1 is to check understanding of UCG. It is too long to do TA adjustment every 256 ms. It is not sufficient as timing drift can be in the order of 5 us during 256 ms  ***Q2: In case UE pre-compensation is done slot-by-slot / over a number of slots N in long PUSCH repetitions re-using legacy UCG***   * ***What is the value of N – i.e. 1, 8, 16*** * ***Can feasibility of this method be up to UE implementation?***   Q2: This solution should be the baseline. Value of N can be discussed in the WID phase.  Our understanding is that UE can read NTN SIB with ephemeris at time t=n and calculate the amount of pre-compensation for delay and Doppler shift over several seconds. Depending on UE implementation, the UE can apply UE pre-compensation Slot-by-slot or over N slots during the long PUSCH transmission. New gap seems not necessary. The value of N can be 1, 8, 16. It can be up to the UE implementation. Note that if N=1, the TA drift in LEO = 600 km is 0.02 us (20 us/s \* 1ms/1000 ms). This is much smaller than the transmit timing error Te=80\*Ts=2.6 us for NB-IoT and Te=24\*Ts=0.78 us for eMTC.  ***Q3: In case of segmented pre-compensation in long PUSCH repetitions with new gaps***   * ***What is the assumption for maximum variation of delay and Doppler shift for segmented pre-compensation?*** * ***What is the new gap periodicity and duration?***   We do not see a need for segmented pre-compensation. We see no serious issue from implementation for Q2 which should be the baseline as discussed above. We have concern that this new gap would have high impact on the specifications un-necessarily. |
| Nokia, NSB | Q1: In LTE NB-IoT/eMTC, it is not allowed to update TA in duration of repetitions according to TS 36.133 v16.6.0,   * **7.20 UE transmit timing for NB-IoT**   When a repetition period is configured on the uplink for which R>1, the UE shall not adjust the uplink transmission timing autonomously during an ongoing repetition period other than at initial transmission as defined above.   * **7.24 UE transmit timing for Category M1**   When a repetition period is configured on the uplink for which R>1, the UE shall not adjust the uplink transmission timing autonomously during an ongoing repetition period other than at initial transmission as defined above.  Q2: the TA adjustment requested in IoT NTN depends on the timing drift rate in different scenarios, as network is the one who knows about the scenario for timing drift rate, it should be network to configure the TA adjustment(s) in repetitions.  Q3: as mentioned in answer for Q2, the TA adjustment value and time to apply will depend on scenario, but it should guarantee that the transmission after TA adjustment should fall into the cyclic prefix. |
| SONY | The moderator’s text states:   * In NB-IoT deep coverage / eMTC Coverage mode A at MCL=154 dB, a transmission time of several hundred ms for the long PUSCH is adequate (this allows transmission of a packet at SNR as low as -10 dB). * In NB-IoT extreme coverage / eMTC Coverage mode B at MCL=164 dB, a transmission time of several hundred ms for the long PUSCH is adequate (this allows transmission of a packet at SNR as low as -20 dB).   Surely, the transmission times for 154dB and 164dB MCL should be different. Shouldn’t the 164dB MCL be “several seconds”?  Our proposal on “Sony propose the UE updates the timing of its PUSCH transmissions every ‘N’ ms, ” can be classified under the “segmented pre-compensation” text.  Our responses to moderator questions are:  Q1: pre-compensation should be shorter than once every 256ms, e.g. every 8 or 16ms  Q2: If compensation is done on a slot-by-slot basis, this can be up to UE implementation. However, we are concerned that there would be issues of PAPR due to lack of waveform continuity and there may be issues with being able to perform cross-subframe channel estimation at the eNB.  If pre-compensation changes every N subframes: |
| Ericsson | Q1: Yes, but more frequent updates of the pre-compensation are needed.  Q2: N depends on the scenario and the acceptable time/frequency offset which is FFS. With a small N the TA adjustment step will be small (a few % of the CP length) and it may be possible to adjust TA without transmission gaps. We are not sure what “reusing legacy UCG” means here since these are much less frequent.  Q3: The necessity of segmented pre-compensation should first be justified. |
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#### FIRST ROUND – Long UL transmission on PUSH

CATT, GateHouse, ZTE, Eutelsat, Xiaomi, Huawei, CMCC, Apple, Qualcomm, MediaTek, Spreadtrum, APT, Nokia, SONY, Ericsson provided comments

Companies were encouraged to comment on ways UE can apply the pre-compensation of delay and Doppler shift during long PUSCH transmission:

Based on comments CATT, Xiaomi, Huawei, CMCC, Apple, ZTE, Apple, Qualcomm, APT, Spreadtrum, Nokia the moderator view is that companies share same understanding on

* Q1: UCG and need for UE pre-compensation to be applied by UE for shorter UL transmission than 256 ms.
* Q2: UE pre-compensation done slot-by-slot / over a number of slots N. The value of N can be determined later. This requires specification change based on TS 36.133 Section 7.20 and 7.24.

Qualcomm, MediaTek commented UE pre-compensation done slot-by-slot / over a number of slots N should be the baseline, and do not see a need for new gaps for sporadic short transmissions.

Moderator correction based on SONY’s comment:

* In NB-IoT deep coverage / eMTC Coverage mode A at MCL=154 dB, a transmission time of 250 hundred ms for the long PUSCH assuming a 50B packet is adequate (this allows transmission of a packet at SNR as low as -10 dB).
* In NB-IoT extreme coverage / eMTC Coverage mode B at MCL=164 dB, a transmission time of 1.5 second for the long PUSCH assuming a 50 Bytes is adequate (this allows transmission of a packet at SNR as low as -20 dB).
* SONY proposal on “Sony propose the UE updates the timing of its PUSCH transmissions every ‘N’ ms, ” can be classified under the “segmented pre-compensation” text. Maximum variation of delay is 5 us / second. This value considers both service and feeder links. With segments lasting for N=8ms or N=16ms. If the timing is updated every 8 – 16ms, there is no need for gaps.

The moderator view is that new gaps for long PUSCH need more discussion. There is shared understanding that more frequent updates of the pre-compensation than every 256 ms are needed. Based on SONY’s comments, it seems there is confusion between segmented UE pre-compensation (i.e. applied over N slots) and UL gap. This confusion comes from the lack of clarity on what the UE is supposed to do during the gap. This needs to be further discussed.

***FL recommendation – Section 2.3.2.1:***

***Companies are encouraged to further discuss aspects of long PUSCH transmission w.r.t. (segmented) UE pre-compensation (slot-by-slot or over N slots) without UL gap, segmented UE pre-compensation (slot-by-slot or over N slots) with UL gap. Companies are also encouraged to provide more analysis and discussions on the scenarios and the expected behaviour of the UE during the new gaps if configured - i.e. scenario / use case targeted (sporadic short transmission, long connection, ..), whether UE is supposed to read NTN SIB carrying the ephemeris.***

***First round proposal – Section 2.4.1.1:***

* ***UE pre-compensation done slot-by-slot / over a number of slots N for long PUSCH is baseline solution.***

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| Company | Comments |
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## Long transmission on PRACH

The following agreements were made in RAN1#104e:

Agreement:

Study the UE pre-compensation of satellite delay and Doppler during long UL transmission on PRACH in NB-IoT and eMTC.

The delay drift can be up to 20 us/s on service link or feeder link. NB-IoT UE supports three CP lengths, 66.7us, 266.7us, and 800us. The maximum transmit error for NB-IoT is 80\*Ts=2.6 us (for eMTC it is 24\*Ts=0.78 us) [TS 36.133, section 7.1.2 and 7.20.2]. The maximum number of NPRACH transmission is 1024 in NB-IoT, which gives a total RACH transmission of about 20 s. With the maximum time duration of PRACH preamble and without UE pre-compensation of satellite delay, the transmit timing error requirement cannot be met and the cyclic prefix is not large enough for any of the RACH preamble formats.

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| --- | --- | --- | --- | --- |
| Preamble format | P |  |  | Duration of one repetition |
| 0 | 4 |  |  | 5.6ms |
| 1 | 4 |  |  | 6.4ms |
| 2 | 6 |  | 3 | 19.2ms |

In the NB-IoT specification 36.211, the NPUSCH UL Compensation Gap (UCG) definition is given as

* *NPRACH transmission can start only Nstart NPRACH ⋅30720Ts time units after the start of a radio frame fulfilling nf mod(Nperiod NPRACH /10)= 0 . For frame structure type 1, after transmissions of 4⋅ 64(TCP + TSEQ ) time units for preamble formats 0 and 1, or 16 ∙ 6(𝑇𝐶𝑃 + 𝑇𝑆𝐸𝑄) time units for preamble format 2, a gap of 40 ⋅ 30720Ts time units shall be inserted.*

Huawei mentioned RACH failure due to long RACH transmission of up to 20 seconds. Moderator view is similar to that for the maximum long PUSCH duration discussed in previous Section 2.4. A more practical RACH transmission in the order of a second or several seconds at MCL=154 dB or 164 dB should be sufficient for the considered IoT NTN scenarios.



Pre-compensation in long PRACH repetition re-using legacy UCG:

APT observed that NPRACH transmission supports 40ms of UCG after transmission of 256ms. In 256ms, the total drift is around 6.4 us that can be supported by the NRACH preambles. For long transmission on PRACH, no enhancement is needed, and reusing the legacy 40ms of UCG for NPRACH transmission shall be considered.

Huawei, MediaTek, Ericsson, APT proposed UE apply autonomous TA adjustment are applied during the long preamble transmission to compensate the satellite timing drift.

MediaTek, Ericsson proposed UE pre-compensate Doppler shift during the long preamble transmission to compensate the satellite Doppler drift.

Based on the moderator understanding, more discussions is needed to check understanding of the issues with long PRACH transmissions and how the UE pre-compensation could be determined and applied by the UE. The UE pre-compensation can be applied to satellite delay and Doppler shift.

***Initial Proposal – Section 2.5:***

***Companies are encouraged to comment on ways UE can apply the pre-compensation of satellite delay and Doppler shift during long PRACH transmission:***

* ***Q1: Is it company understanding that UE pre-compensation can be applied at least once every 256 ms during specified UCG in case of long PRACH transmission greater than 256 ms.***
* ***Q2: In case UE pre-compensation is done slot-by-slot / over a number of slots N in long PRACH repetitions re-using legacy UCG***
  + ***What is the value of N***
  + ***Can feasibility of this method be up to UE implementation?***

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| Company | Comments |
| CATT | Q1: pre-compensation period could be shorter than 256ms  Q2: exact value of N is up to GP duration. Due to GP protection, PRACH pre-compensation adjustment could be implemented by UE itself. |
| ZTE | Q1: same comments as Question for section 2.4.  Q2: same comments as Question for section 2.4. It’s not preferred to done by implementation, and detailed value of N is up to scenarios. |
| Xiaomi | Q1: yes  Q2: 1) The value of N can be determined later.  2) It should be pre-configured. |
| Huawei | Q1: 256ms time continuous for PRACH is too long and the timing drift can as high as hundreds of Ts for LEO600km. In NB-IoT, the UL gap for PRCAH is inserted after a specific number of repetitions. For IoT over NTN, an UL gap can also be inserted after several number of repetitions but the number should be fixed for different types of PRACH. As the variation of delay and Doppler shift is related to the elevation and satellite velocity the maximum time continuous repetition number can be configured by the NW, e. g. indicated in the cell specific information according to the minimum elevation of the cell. |
| CMCC | Q1: yes.  Q2: If UE know the TA drift, why not adjust its UL transmission frequency (i.e., in symbol-by-symbol level)? Which is beneficial for the eNB to perform channel estimation. Otherwise, if UE doesn’t know the TA drift, UE cannot do the pre-compensation no matter done slot-by-slot or over a number of slots N. |
| Apple | Q1: In case of PRACH transmission greater than 256 ms, the UE pre-compensation should be applied at least once every X ms, where X should be less than 256 considering the moving satellite.  Q2: The value of N may depend on scenario (e.g., larger value for GEO and smaller value for LEO) and satellite ephemeris. |
| Qualcomm | Same comments as in the proposal for Section 2.4 on PUSCH |
| MediaTek | We have similar comments as in Section 2.4 for long PUSCH |
| Spreadtrum | Q1: The period and duration of UCG may needed to be enhanced.  Q2: 1) The value of N can be determined later.  2) Pre-configured. |
| APT | Q1: Yes  Q2: If the preamble transmission has an overlap due to repetition, then there is no UE behavior in this release. We may have more spec impacts if slot-based pre-compensation is supported in initial access. |
| Nokia, NSB | See answer in 2.4 Q1/Q2/Q3. |
| SONY | Same answers as 2.4 |
| Ericsson | Similar comments as in Section 2.4. |
| SONY | Same answers as 2.4 |
| Ericsson | Similar comments as in Section 2.4. |

### FIRST ROUND -Long transmission on PRACH

CATT, ZTE, Eutelsat, Xiaomi, Huawei, CMCC, Apple, Qualcomm, MediaTek, Spreadtrum, APT, Nokia, SONY, Ericsson provided comments

Companies were encouraged to comment on ways UE can apply the pre-compensation of delay and Doppler shift during long PRACH transmission:

Based on comments CATT, Xiaomi, Huawei, CMCC, Apple, ZTE, Apple, Qualcomm, APT, Spreadtrum, Nokia, the moderator view is that companies share same understanding and views as discussed in previous Section for the long PUSCH.

The moderator view is that new gaps for long PRACH need more discussion. We make similar FL recommendation and first round proposal as in previous section for the long PRACH

***FL recommendation – Section 2.5.1:***

***Proponents of new gaps are encouraged to provide more analysis and discussions on the scenarios and the expected behaviour of the UE during the new gaps - i.e. scenario / use case targeted (sporadic short transmission, long connection, ..), whether UE is supposed to read NTN SIB carrying the ephemeris, whether they see an issue with the “baseline” solution requiring new gaps, periodicity and duration of the gaps, and so on) for the long PRACH.***

***First round proposal – Section 2.5.1:***

* ***UE pre-compensation done slot-by-slot / over a number of slots N for long PRACH is baseline solution.***

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| Company | Comments |
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## DL Synchronization

DL synchronization and PBCH coverage were discussed in RAN1#104e. There was no consensus on the issues and options. Moderator made the following recommendations:

* Proponents are encouraged to provide more analysis and evaluation to help understanding whether there is an issue with DL synchronization performance.
* Proponents are encouraged to provide more analysis and evaluation to help understanding whether there is an issue with (N-)PBCH coverage.

Huawei, ZTE, CATT, Qualcomm, MediaTek observed differential frequency shift in IoT NTN and crystal error may become larger than the existing channel raster in some deployment.

ZTE observed in case of IoT over NTN service in S-band (e.g., at 2 GHz) with UE oscillator error as 20 ppm (NB-IoT UE) and the residual Doppler as 16.14 ppm (e.g., LEO-600, 1000 km beam diameter for nadir beam), the maximum FO could be up to (20 + 16.14)\*2 = 72.28 kHz, which is much larger than half of the current channel raster, i.e., 100 kHz. ZTE showed NPSS simulations with SNR=-13.95 dB, CFO=±47.5kHz require over 1 second to achieve accurate DL synchronization.

ZTE, CATT, Qualcomm, MediaTek proposed to increase the channel raster size.

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| --- | --- | --- | --- |
| **Satellite** | **Set 3** | **Set 3** | **Set 4** |
| **Satellite orbit** | LEO-1200 | LEO-600 | LEO-600 |
| **Satellite altitude** | 1200 km | 600 km | 600 km |
| **Central beam edge elevation** | 30 degree | 30 degree | 30 degree |
| **Central beam center elevation** | 46.05 degree | 43.8 degree | 90 degree |
| **Beam diameter size** | 1110.09Km | 610.8Km | 1701.8Km |
| **Differential Doppler** | +/-21.56KHz | +/-21.14KHz | +/-39.9KHz |

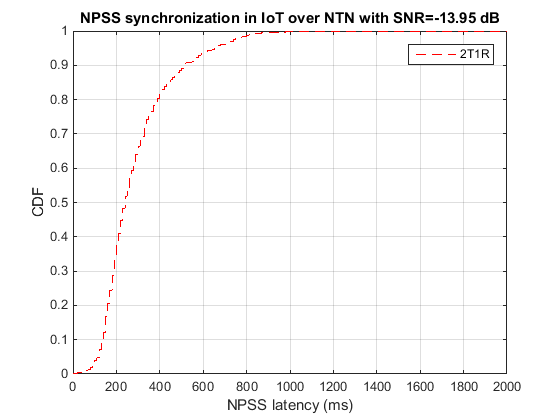


Figure: NPSS synchronization performance for In-Band mode, SNR=-13.95 dB, CFO=±47.5kHz (Source ZTE)

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| --- | --- | --- |
| Performance Metrics | In-Band Mode, 1T1R | In-Band Mode, 2T1R |
| Detection probability | 64.84% | 91.41% |
| Synchronization Latency (50%) | 620 ms | 240 ms |
| Synchronization Latency (90%) | 1540 ms | 520 ms |
| Synchronization Latency (95%) | 1700 ms | 665 ms |
| Residual frequency offset (95%) | -540Hz~540Hz | -380Hz~380Hz |

Table: NPSS synchronization performance with SNR=-13.95 dB (Source ZTE)

Qualcomm, MediaTek also proposed another solution is to include a portion of the ARFCN in the (NB-)MIB

Huawei proposed indication of DL frequency pre-compensation is normalized to a predefine subcarrier spacing. To reduce the signaling overhead, only DL pre-compensation indication is needed and sufficient for UL frequency alignment.

***Initial Proposal - Section 2.6:***

* ***New Channel raster increased from 100 kHz***

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| Company | Comments |
| CATT | Support this proposal. |
| GateHouse | Agree that the ARFCN can be indicated in the MIB. One bit could just indicate whether it is an even or odd number. |
| ZTE | Supportive to extend the raster directly. |
| Xiaomi | Support the proposal. |
| Eutelsat | Support the proposal from Qualcomm/ MediaTek. An indication of ARFCN (indication need not be the complete ARFCN, e.g. as suggested by GateHouse, odd/even) may be sufficient to resolve ambiguity. |
| Huawei | Fine with proposal. |
| CMCC | Support the proposal. |
| Qualcomm | While both options—increasing the raster size, as well as indicating a portion of the ARFCN in MIB—“work”, there is a drawback to increasing the raster size, in the sense that, one can pack less Ncells within a given frequency.  The “(part of) ARFCN-indication-in-MIB” approach mitigates this problem; as a result, we prefer this approach to solving the DL synchronization issue. |
| MediaTek | Support increased channel raster. |
| Spreadtrum | Support |
| APT | Support Initial Proposal - Section 2.6.  However, if “always-on” CRS is introduced, and if it can improve NPSS synchronization performance, then we wonder whether the New Channel Raster (may be 200kHz) is needed. |
| Nokia, NSB | Based on 100kHz raster, although UE may mis-detect the raster, but it may only have 2 raster for further search on PDCCH for SIB. It may take double time for UE to detect the PDCCH but as it is only once before UE initial access, it will not impact a lot. And history-based detection can be used by UE to avoid the additional latency for detection. |
| SONY | OK to consider a different raster for IoT-NTN. |
| Ericsson | This needs to be discussed with RAN4. |

### FIRST ROUND – DL synchronization

CATT, GateHouse, ZTE, Eutelsat, Xiaomi, Huawei, CMCC, Qualcomm, MediaTek, Spreadtrum, APT, Nokia, SONY, Ericsson provided comments

Based on comments CATT, Xiaomi, Huawei, CMCC, Apple, ZTE, Apple, Qualcomm, APT, Spreadtrum, Nokia, Eutelsat, the moderator view is that companies share same understanding that there is an issue with DL synchronization due to the satellite Doppler shift and internal crystal frequency error in device. Two solutions are considered:

New Channel raster increased from 100 kHz

* Supported by 10 companies CATT, ZTE, Xiaomi, Huawei, CMCC, Spreadtrum, APT, MediaTek (preference), Qualcomm, SONY

“(part of) ARFCN-indication-in-MIB

* Supported by 4 companies Gatehouse, Eutelsat, MediaTek, Qualcomm (preference)

Nokia observed that based on 100kHz raster, although UE may mis-detect the raster, but it may only have 2 raster for further search on PDCCH for SIB. It may take double time for UE to detect the PDCCH but as it is only once before UE initial access, it will not impact a lot. And history-based detection can be used by UE to avoid the additional latency for detection.

Ericsson commented this needs to be discussed in RAN4.

The moderator view is that in case an increased DL channel raster is used, the usefulness on also using “(part of) ARFCN-indication-in-MIB is questionable; likewise “(part of) ARFCN-indication-in-MIB is used it seems not useful to also use increased DL channel raster. Further study is needed.

***First round proposal - Section 2.6.1:***

***Down-scope solutions for DL synchronization for Rel-17***

* ***New Channel raster increased from 100 kHz is baseline solution for Rel-17***
* ***“(part of) ARFCN-indication-in-MIB***

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| Company | Comments |
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## Other

## Functionalities

In this section, it is considered to capture observations and proposals from contributing companies on the studied topics additionally (to the essential proposals) in the TR as guiding principles and observations for future work in future releases.

### UE TA report

ZTE, MediaTek proposed UE report its autonomously acquired TA. Samsung proposed this is further studied.

### Closed-loop time-frequency corrections

Qualcomm observed that for long connections in eMTC and NB-IoT over NTN, (N)PRACH-driven closed-loop time and frequency corrections lowers the GNSS power penalty from  **to**  (with a GNSS relaxation factor of 4), w.r.t a baseline without closed-loop corrections.

* Such an (N)PRACH-driven closed loop correction may be facilitated by a periodic or semi-persistent CFRA transmission from the UE, followed by a response message from the network.
* An NPRACH design that is robust to time and frequency errors (e.g., the one based on restricted preambles in Section 6 of this contribution) is especially suitable for this.

Qualcomm proposed to include observation in the TR, in the context of current or future study and support of long connections for eMTC and NB-IoT over NTN, as it relates to uplink synchronization aspects.

### Alternate starting subcarriers for NPRACH transmissions

Qualcomm proposed RAN1 to consider potential enhancements to (N)PRACH design, depending on the requirements for satellite location accuracy and UE’s own geolocation accuracy at the UE.

- The design should also consider facilitating closed-loop time and/or frequency corrections.

Qualcomm observed that restricting alternate starting subcarriers for NPRACH transmissions allows to correct for potentially large initial uplink frequency synchronization errors (e.g., up to 1 kHz)

- Such a scheme may facilitate UE power savings by relaxing the frequency and accuracy of GNSS fixes and/or satellite ephemeris reads required.

- Such a scheme may also facilitate NPRACH-driven closed-loop corrections of time and frequency errors in connected mode, thereby reducing the power penalty from frequent GNSS fixes.

Qualcomm proposed to include observation in the TR, in the context of current or future study for eMTC and NB-IoT over NTN, as it relates to uplink synchronization aspects.

***Initial Proposal – Section 2.7:***

***Companies are encouraged to comment on***

* ***2.7.1 UE TA report***
* ***2.7.2 Closed-loop time-frequency corrections***
* ***2.7.3 Alternate starting subcarriers for NPRACH transmissions***

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| Company | Comments |
| CATT | UE TA reporting is needed in order to help network to adjust the schedule timing with good accuracy. |
| GateHouse | Support this interesting proposal |
| ZTE | W.r.t the TA report: for ensuring the well configured offset for scheduling, the TA report should be needed with further consideration on the impacts of long transmission.  W.r.t the close loop correction, it’s fine set the mechanism for timing only.  W.r.t the PRACH, if the pre-comepensation is failed to be supported in IoT-NTN, enhancement on PRACH can be considered. |
| Xiaomi | Wait for NR NTN progress. The first two bullets can be determined later. |
| Eutelsat | Support the proposal – all ideas which, upon further study, could be interesting (even if in R18+), such as those that could reduce device power consumption, should be captured in the TR. |
| Huawei | TA report is needed so that a proper K\_offet can be configured by the eNB to avoid the UL and DL collisions.  Closed-loop time-frequency corrections should be postponed as other synchronization issues including NTN SIB reading, GNSS measurement and accuracy of ephemeris have not fully discussed.  Alternate starting subcarriers for NPRACH transmission is not preferred as the available resources for PRACH will be reduced which will cause more PRACH congestion. Preambles with adjacent frequency resources can be transmitted in different ROs or allocated with different time offset within one RO period. |
| Apple | UE TA report may be useful for HD-FDD UEs, for simultaneous UL-DL transmissions avoidance. |
| Qualcomm | * ***2.7.1 UE TA report***   **UE reporting of TA is essential in multiple contexts**. For half-duplex UEs, there isn’t a way to do scheduling at the network without knowing the UE’s (autonomously determined) TA.   * ***2.7.2 Closed-loop time-frequency corrections***  1. For “short, sporadic connections”, this is not essential—we specifically state this in our contribution. 2. However, we **strongly recommend to document in the TR, the use case and solutions pertaining to “long connections”—i.e., ones that are >~10 seconds**. Otherwise, we are going to needlessly cripple NB-IoT/eMTC’s functionality down over NTN, down the line, w.r.t that over terrestrial networks. In this regard, we extensively demonstrate how, **for long connections, replacing repeated GNSS fixes (e.g., for mobile UEs, such as UEs in a tracking application) with closed-loop time/frequency correction commands, dramatically reduces the battery life penalty (from 45% to 17% or less)**. The documentation of such observations is essential for future evolution—beyond just the narrow scope of Release 17—to keep IoT-NTN competitive in the long run.  * ***2.7.3 Alternate starting subcarriers for NPRACH transmissions***   At the outset, we would like to clarify that **we are not saying “every set of NPRACH subcarriers” have to have this resource restriction**; we are proposing this as an **option for “some” occasions**, so as to provide **better robustness** of frequency-synchronization for UEs, while at the same time, **saving significant amounts of UE power by reducing the number of GNSS fixes required** to maintain uplink sync (e.g., in long connections).  This may be useful in several scenarios, such as:   * For UEs with limited/poor GNSS reception condition/capability * To relax the no. of GNSS fixes required to maintain uplink frequency synchronization, thereby saving significant amounts of UE power * To facilitate closed-loop correction of a larger range of frequency offsets   We believe description (and support of) this simple solution to make the uplink synchronization significantly more robust and significantly less power-hungry **should be considered strongly by RAN1—at a minimum, documented as a simple-yet-beneficial solution for enhanced uplink synchronization, in the TR.** |
| MediaTek | • 2.7.1 UE TA report  We think this is beneficial in Rel-17 without high impact on specifications.   * ***2.7.2 Closed-loop time-frequency corrections***   Not essential in Rel-17   * ***2.7.3 Alternate starting subcarriers for NPRACH transmissions***   Not essential in Rel-17  We are fine to document these solutions in the TR. |
| APT | Q1: at least support TA report in RRC\_IDLE  Q2: non-essential  Q3: non-essential |
| Nokia, NSB | For 2.7.1, It will be complicated if UE frequent report TA when it changes. Also it will cause large overhead and power consumption in UL where repetitions will be needed. We propose a location based reporting, to avoid overhead and power consumption, also with good accuracy.  For 2.7.2, FFS on how much margin left after TA adjustment from network, with or without UE assistance  For 2.7.3, FFS |
| SONY | 2.7.1 support TA report.  2.7.2 / 2.7.3 These can be studied and documented in TR |
| Ericsson | 2.7.1 should be discussed under agenda item 8.15.3.  2.7.2 and 2.7.3 are non-essential. |

### FIRST ROUND - Functionalities

CATT, GateHouse, ZTE, Xiaomi, Eutelsat, Huawei, Apple, Qualcomm, MediaTek, APT, Nokia provided comments:

• 2.7.1 UE TA report

• 2.7.2 Closed-loop time-frequency corrections

• 2.7.3 Alternate starting subcarriers for NPRACH transmissions

Based on comments UE TA report has wide support (9 companies).

* Supported by CATT, Huawei, Apple, Qualcomm, MediaTek, APT, Gatehouse, Eutelsat, SONY
* Not supported by Nokia (UE frequent report TA when it changes increases overhead and power consumption), Xiaomi (wait for NR NTN progress first)

Ericsson commented UE TA report should be discussed in 8.15.3

Closed-loop time-frequency corrections

* Qualcomm commented not essential for sporadic short connections, but recommended to document in the TR for the use case and solutions pertaining to “long connections”—i.e., ones that are >~10 seconds.
* ZTE commented only time-correction mechanism,

Alternate starting subcarriers for NPRACH transmissions

* Huawei commented concern on reduction in available resources for PRACH will cause more PRACH congestion.
* Qualcomm commented useful in several scenarios (For UEs with limited/poor GNSS reception condition/capability, To relax the no. of GNSS fixes required to maintain uplink frequency synchronization, thereby saving significant amounts of UE power, To facilitate closed-loop correction of a larger range of frequency offsets

Xiaomi, Huawei commented to wait for NR NTN progress. MediaTek, SONY commented fine to study and document these solutions in TR as guiding principles and observations for future work in future releases.

***Moderator view:***

***There is interest from a majority of companies commenting the following solutions:***

* ***Alternate starting subcarriers for NPRACH transmissions for enhanced uplink synchronization.***
* ***Closed-loop time-frequency corrections for discussions on the use case and solutions pertaining to “long connections”***

***These solutions can be further discussed in May meeting for decision to include these in TR as guiding principles and observations for future work in future releases***.

***FL recommendation – Section 2.8.4:***

* ***Proponent of UE TA report are encouraged to provide more analysis to determine whether it essential for scheduling Half-Duplex UEs Rel-17***

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| Company | Comments |
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## Useful optimizations

In this section, proposals from contributing companies for useful optimizations are considered.

### PBCH coverage enhancement

Qualcomm proposed to include the first three symbols in a subframe as well as the REs corresponding to the 4 CRS ports for rate matching the NPBCH.

### Non-RLF mechanisms for handling outdated ephemeris/GNSS information

Qualcomm proposed RAN1 to consider non-RLF mechanisms for handling outdated ephemeris/GNSS information including:

* UE triggered scheduling gap, prioritizing re-acquiring synchronization, e.g., via reading SIB.
* Transmission of specially designated (N)PRACH preambles, and reception of corresponding closed-loop correction commands.
* Other relevant solutions.

### Dedicated unicast transmission of satellite location information

Qualcomm proposed RAN1 to consider, in addition to the SIB-based broadcast mode of transmission, a dedicated unicast transmission of satellite location information to UEs.

* Such a dedicated transmission may precede an uplink grant, to ensure maintenance and better accuracy of uplink synchronization, and minimize synchronization failure events.
* An example of the above would be for a DCI that schedules an uplink transmission to also schedule a downlink (N)PDSCH, carrying satellite location information, preceding the uplink grant.

### Network controlled pre-compensation

Nokia proposed there may be UE GNSS unavailable/fault, where solution with only UE GNSS based auto-pre-compensation can not work well. Actually, GNSS based measurement can provide UE a good reference for adjustment on oscillator, then based on a correct oscillator, one possible way is UE can adjust time based on TimeReferenceInfo-r15 from eNB without impact from satellite location derivation, while measure DL RS for UL frequency adjustment without impact by UE location derivation and satellite location derivation. The later solution, i.e. time reference configured from eNB and DL RS based UL synchronization is more stable while not impacted by GNSS issue, with regular DL measurement and configuration supported by specification of IoT over TN. Nokia proposed combination of UE automatic pre-compensation and network controlled pre-compensation should be studied and utilized, to provide effective UL synchronization for all type of UE in all IoT NTN scenario, and to provide fast convergence of UL synchronization.

***Initial Proposal – Section 2.8:***

***Companies are encouraged to comment on***

* ***2.8.1 PBCH coverage enhancement***
* ***2.8.2 Non-RLF mechanisms for handling outdated ephemeris/GNSS information***
* ***2.8.3 Dedicated unicast transmission of satellite location information***
* ***2.8.4 Network controlled pre-compensation***

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| Company | Comments |
| CATT | For these issues, in our view, it is not essential. |
| GateHouse | On the surface it looks like a large amount of overhead.  If such signalling were to be implemented, it would require a DCI to point towards the ephemeris data.  But, at that point you could just as easily define a DCI that points to ephemeris data in the NPDSCH so more UEs can have benefit from the transmission. |
| ZTE | We are supportive on the Non-RLF mechanism for handling the outdated system information. |
| Eutelsat | Appears not to be essential. Fine to study and capture ideas in TR. |
| Huawei | Can be postponed as other issues including NTN SIB reading, GNSS measurement and accuracy of ephemeris have not fully discussed. |
| CMCC | PBCH coverage enhancement seems not essential. |
| Qualcomm | * ***2.8.1 PBCH coverage enhancement***   While we think that for NTN-IoT, there isn’t an “in-band with LTE” deployment mode use case, and as a result, we could have used the LTE control region and CRS REs to increase coverage for NPBCH for IoT NTN, we acknowledge that this isn’t strictly essential.   * ***2.8.2 Non-RLF mechanisms for handling outdated ephemeris/GNSS information***   In the light of the discussions in Section 2.1 on “triggering mechanisms for GNSS”, “GNSS measurement window”, etc., we think it makes sense to **include the solutions we proposed under “non-RLF mechanisms for handling outdated ephemeris/GNSS information” in our contribution, to the TR**. These may be particularly relevant for the “long connection” use case.   * ***2.8.3 Dedicated unicast transmission of satellite location information***   We propose to **“club” this into 2.8.2 above, and include it in the TR**, since this is also—as we have shown—a mechanism to ensure that the UE has the best possible time and frequency synchronization possible for uplink transmissions, **so that it doesn’t run into the “outdated ephemeris information” problem**, that would otherwise result from any of the other solutions.   * ***2.8.4 Network controlled pre-compensation***   We don’t understand the intention/motivation of this proposal very clearly. |
| MediaTek | Discussions on these useful optimizations can be postponed. We also think NTN SIB reading, GNSS measurement and accuracy of ephemeris have not been fully discussed. |
| Spreadtrum | These useful optimizations can be postponed. |
| APT | Good to have, but non-essential |
| Nokia, NSB | For 2.8.1, For DL PSS/SSS/PBCH, we suggest evaluation should be done as for NR SSB in NTN, with agreed assumptions after discussion, to confirm whether there is issue  For 2.8.2, It should be studied whether normal action after failure can work or not.  For 2.8.3, it should be firstly make it clear on solutions of sync, then 2nd step as whether it is requested  For 2.8.4, we can call it network based pre-compensation.  **If only consider UE automatic pre-compensation, there will be**   * **UL synchronization error for IoT UE in NTN scenario** * **The syncrhnizaiton error may last for long time with repeeitions and error propagation,** * **Mis-alignement between UE and eNB and ineffective for UL sync adjustment.**   ***Network based pre-compensation*** should be defined to work together with GNSS based pre-compensation, to to provide effective UL synchronization for all type of UE in all IoT NTN scenario, especially when there is GNSS inaccuracy/unavailability issue, and to provide fast convergance of UL synchronization.  **Combination of UE automatic precompensation and network based precompensation should be studied and utilized, to provide effective UL synchronization for all type of UE in all IoT NTN scenario, and to provide fast convergance of UL synchronization.** |
| SONY | We are open to study these issues, but feel they are not essential functionality.  There are a set of issues related to timing advance that need to be discussed. My assumption was that they would be studied under AI8.15.2, but this does not seem to be the case. We made the following proposals in our Tdoc ([20] [R1-2103319](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_104b-e/Docs/R1-2103319.zip)) related to timing advance:  **Proposal 2: The eNB signals the rate of change of subframe timing on the feeder link, or timing drift rate, to the UE. The UE adds the timing drift rate on the feeder link to the rate of change of subframe timing on the service link to determine the timing adjustments that are applied during long UL transmissions.**  **Proposal 3: A timing advance command is associated with a reference point. The reference point indicates which node (UE, eNodeB or satellite) the timing advance command refers to.**  **Proposal 4: A timing advance command is associated with a reference time. The reference time indicates the time at which the timing advance is valid. The reference time of the timing advance command can be signaled to the UE either in MAC CE or PDCCH.**  **Proposal 5: The motion of the NTN aerial platform is signaled to the UE using position and velocity information and the drift rate of the timing on the feeder link.**  **Proposal 6: The position / velocity / drift rate (PVD) information is signaled using SIB signalling.**  If these issues are not going to be considered here, where are they going to be considered? AI8.15.3? RAN2? |
| Ericsson | These optimizations are non-essential. |

### FIRST ROUND – Other

CATT, GateHouse, ZTE, Eutelsat, Huawei, CMCC, Qualcomm, MediaTek, Spreadtrum, APT, Nokia provided comments on proposal to comment of the following:

* 2.8.1 PBCH coverage enhancement (CMCC not essential)
* 2.8.2 Non-RLF mechanisms for handling outdated ephemeris/GNSS information (supported by ZTE)
* 2.8.3 Dedicated unicast transmission of satellite location information
* 2.8.4 Network based pre-compensation (Qualcomm not clear intention/motivation of proposal)

CATT, Eutelsat, APT, Ericsson commented not essential. Huawei, Spreadtrum, MediaTek commented can be postponed. Nokia commented further study. SONY commented study in 8.15.2.

Qualcomm commented:

2.8.1: PBCH coverage enhancement: While we think that for NTN-IoT, there isn’t an “in-band with LTE” deployment mode use case, and as a result, we could have used the LTE control region and CRS REs to increase coverage for NPBCH for IoT NTN, we acknowledge that this isn’t strictly essential.

2.8.2 Non-RLF mechanisms for handling outdated ephemeris/GNSS information: In the light of the discussions in Section 2.1 on “triggering mechanisms for GNSS”, “GNSS measurement window”, etc., we think it makes sense to include the solutions we proposed under “non-RLF mechanisms for handling outdated ephemeris/GNSS information” in our contribution, to the TR. These may be particularly relevant for the “long connection” use case.

2.8.3 Dedicated unicast transmission of satellite location information: We propose to “club” this into 2.8.2 above, and include it in the TR, since this is also—as we have shown—a mechanism to ensure that the UE has the best possible time and frequency synchronization possible for uplink transmissions, so that it doesn’t run into the “outdated ephemeris information” problem, that would otherwise result from any of the other solutions.

2.8.4: Network based pre-compensation: Nokia commented on Network based pre-compensation should be defined to work together with GNSS based pre-compensation, to provide effective UL synchronization for all type of UE in all IoT NTN scenario, especially when there is GNSS inaccuracy/unavailability issue, and to provide fast convergence of UL synchronization. Combination of UE automatic pre-compensation and network based pre-compensation should be studied and utilized, to provide effective UL synchronization for all type of UE in all IoT NTN scenario, and to provide fast convergence of UL synchronization.

***FL Recommendation -Section 2.9:***

***There is some interest from companies commenting the solutions discussed above:***

* ***2.8.1 PBCH coverage enhancement (CMCC not essential)***
* ***2.8.2 Non-RLF mechanisms for handling outdated ephemeris/GNSS information (supported by ZTE)***
* ***2.8.3 Dedicated unicast transmission of satellite location information***
* ***2.8.4 Network based pre-compensation (Qualcomm not clear intention/motivation of proposal)***

***These solutions can be further discussed in May meeting, and decision to include these in TR can then be also be discussed then.***

|  |  |
| --- | --- |
| Company | Comments |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

# Conclusions

We list first round proposals for GTW Session

***First round proposal – Section 2.2.1:***

* ***Capture in TR 36.763, moderator’s summary GNSS Position fix impact on UE power consumption in Appendix A Section 5.1***

***First round proposal – Section 2.3.1.1:***

***Conclusion***

* ***The required power consumption for SIB reading is not significant for short sporadic connections use case prioritized in Rel-17.***

***First round proposal – Section 2.3.2.1:***

***Conclusion***

* ***The UE does not need to read SIB containing satellite location information for short sporadic connections use case prioritized in Rel-17***

***First round proposal – Section 2.4.1.1:***

* ***UE pre-compensation done slot-by-slot / over a number of slots N for long PUSCH is baseline solution.***

***First round proposal – Section 2.5.1:***

* ***UE pre-compensation done slot-by-slot / over a number of slots N for long PRACH is baseline solution.***

***First round proposal - Section 2.6.1:***

***Down-scope solutions for DL synchronization for Rel-17***

* ***New Channel raster increased from 100 kHz is baseline solution for Rel-17***
* ***“(part of) ARFCN-indication-in-MIB***

# References

1. RP-210868, “New Study WID on NB-IoT/eTMC support for NTN”, MediaTek, RAN#91-e, March 2021
2. RP-210915, “Moderator's summary for email discussion [91E][42][NTN\_IoT\_roadmap]”, Ericsson (RAN1 Vice-Chair), RAN#91-e, March 2021
3. RP-210906, Way forward on new proposals, Nokia (RAN Chair), RAN#91-e, March 2021
4. R1-2102344, Huawei, Discussion on time and frequency synchronization enhancement for IoT in NTN, RAN1#104bis-e, April 2021
5. R1-2102423, OPPO, Discussion on enhancements to time and frequency synchronization, RAN1#104bis-e, April 2021
6. R1-2102473, Spreadtrum, Consideration on enhancements to time and frequency synchronization, RAN1#104bis-e, April 2021
7. R1-2102618, CATT, Time and frequency synchronization for NB-IoT/eMTC, RAN1#104bis-e, April 2021
8. R1-2102736, Asia Pacific Telecom, Time and frequency synchronization to NB-IoT in NTN, RAN1#104bis-e, April 2021
9. R1-2102755, MediaTek, Enhancements to time and frequency synchronization for IoT NTN, RAN1#104bis-e, April 2021
10. R1-2102832, Nokia, Enhancement to time and frequency synchronization for NB-IoT/eMTC over NTN, RAN1#104bis-e, April 2021
11. R1-2102906, CMCC, Enhancements to time and frequency synchronization for IoT NTN, RAN1#104bis-e, April 2021
12. R1-2102917, ZTE, Discussion on the synchronization for IoT-NTN, RAN1#104bis-e, April 2021
13. R1-2102973, Xiaomi, Discussion on time and frequency synchronization for IoT NTN, RAN1#104bis-e, April 2021
14. R1-2103056, Intel, On synchronization for NB-IoT and eMTC NTN, RAN1#104bis-e, April 2021
15. R1-2103061, Ericsson, On time and frequency synchronization enhancements for IoT NTN, RAN1#104bis-e, April 2021
16. R1-2103071, Qualcomm, Enhancements to time and frequency synchronization, RAN1#104bis-e, April 2021
17. R1-2103133, Apple, On Time and Frequency Synchronization in IoT NTN, RAN1#104bis-e, April 2021
18. R1-2103267, Samsung, On enhancements to time and frequency synchronization, RAN1#104bis-e, April 2021
19. R1-2103273, Interdigital, Time/Frequency Synchronization for IoT NTN, RAN1#104bis-e, April 2021
20. R1-2103319, Sony, Time and frequency synchronisation enhancements for IoT-NTN, RAN1#104bis-e, April 2021
21. R1-2103528, Lenovo/Motorola, Time and frequency synchronization for IoT NTN, RAN1#104bis-e, April 2021

# Appendix A

In this appendix, evaluation results for UE battery life for eMTC and NB-IoT are provided based on company contributions.

## Moderator summary on GNSS Position fix impact on UE power consumption

In TR 45.820, Section 7.2.4.5.2 provide power consumption assumptions for energy consumption model.

Table 5.4-1: Key input parameters for energy consumption analysis

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| (1) Battery capacity  (Wh) | (2) Battery power during Tx  (mW) | (3) Battery power for Rx (mW) | (4) Battery power when Idle but not in PSS (mW) | (5) Battery power in Power Save State (PSS) (mW) | (6) Time between end of IP packet carrying "report" and start of IP packet carrying "ack" on radio (ms) | (7) Number of reports per day |
| 5 |  |  |  | [0,015] | 1000 |  |
| For each report (refer to Figure 5.4-1): | | | | | | |
| (8) Rx time from PSS exit to re-entry into PSS  (ms) | (9) Idle time from PSS exit to re-entry into PSS  (ms) | (10) Tx time from PSS exit to re-entry into PSS  (ms) | (11) Time from last Rx or Tx activity to entry into PSS1  (ms) |  |  |  |
|  |  |  | 20000 |  |  |  |

Table 7.2.4.5-1: Power consumption assumptions

|  |  |  |
| --- | --- | --- |
| ***Activity*** | ***Power consumption***  ***(mW)*** | ***Comments*** |
| TX active | 545 | Transmitter active at +23 dBm, assuming 44% PA efficiency and 90 mW for other analog and baseband circuitry |
| RX active | 90 | Analog RF and digital baseband processing for active receiver |
| Idle  (light sleep) | 3 | Maintenance of precision oscillator reference for RF synthesizers |
| Deep Sleep | 0.015 | Low power crystal, sleep counters and state machine |



Huawei mention conditions for GNSS TTFF with cold start, warm start, hot start:

* The first is cold start with which no almanac information is stored in the receiver. The UE have to search signals from all the possible satellites and at least 4 satellites are needed for the positioning. Therefore, the duration will be affected by the rate of GNSS signal transmission and quality of reception. The time duration of cold start can range from tens of seconds to more than ten minutes. The typical values of cold start is 30 s if the GNSS signal is received with not much interruption.
* The second start is warm start which is based on the assumption that the some ephemeris information and clock correction data is already obtained. With some available information, the positioning time will be reduced to several seconds.
* The third start is hot start which is based on the assumption that GNSS receiver has valid ephemeris, clock correction and GNSS time reference with time for positioning can be as low as 1~2s.

Assumptions used by contributing companies in battery life analysis with NGSS position fix every UL transmissions:

* GNSS power consumption
  + Integrated GNSS and IoT module:
  + Separate GNSS module and IoT Module: Huawei, MediaTek (100 mW)
* GNSS Position Time To First Fix (TTFF)
  + Hot start: Huawei (1s or 2 s),
  + Warm start: Huawei (several seconds)
  + Cold start: Huawei (30 s)

In order to compare battery life analysis from contributing companies, we align their simulation results case by case based on assumption for reporting (2h and 6h), packet size (50 Bytes), GNSS position TTFF (2s and 5s), MCL = 154 dB assumption (this determines active time for Rx, Tx). This is to ensure there is convergence of methodology. The methodology included all transmissions and receptions in device in energy consumption models.

Separate GNSS module and IoT Module: Huawei, MediaTek (100 mW), CATT (216 mW)

For MediaTek and CATT simulation results we used scaling by 2 to provide figures from 1 day to 12 h to align with Huawei. Note that CATT used GNSS module power consumption of 216 mW; Huawei and MediaTek figures are shown with GNSS module power consumption of 100 mW. The results from companies show reasonable agreement and consistency in observations. At a medium MCL=154 dB, the battery life in NTN is in range 6 years to 16 years; the reduction in battery life is in range 10 % to 40 %.

|  |  |  |
| --- | --- | --- |
| GNSS TTFF (hot start 2s), 2h report | | |
| Source | Huawei  MCL=154 dB, 105 bytes UL, 320 ms report, GNSS 100 mW | MediaTek  MCL=154 dB, 50 bytes UL, 238 ms report, GNSS 100 mW |
| Total active IoT Rx time | 164 ms | 371 ms |
| Total active IoT Tx time | 534 ms | 335 ms |
| Battery life (TN) | 8.6 years | 10.5 years |
| Battery life (NTN) | 6.0 years | 6.9 years |
| Reduction in battery life | 30.2 % | 34.3 % |

|  |  |  |  |
| --- | --- | --- | --- |
| GNSS TTFF (warm start 5s), 12h report | | | |
| Source | Huawei  105 bytes UL, 320 ms report, GNSS 100 mW | MediaTek  50 bytes UL, 238 ms report, GNSS 100 mW | CATT  50 bytes UL, 320 ms report, **GNSS 216 mW** |
| Total active IoT Rx time | 164 ms | 371 ms | 641 ms |
| Total active IoT Tx time | 534 ms | 335 ms | 400 ms |
| Battery life (TN) | 24.3 years | 15.6 years | 15.6 years |
| Battery life (NTN) | 16.2 years | 11.9 years | 9.3 years |
| Reduction in battery life | 33.3% | 23.7 % | 40.4% |

Integrated GNSS and IoT module: Ericsson, MediaTek (37 mW):

Ericsson observed for eMTC/NB-IoT, the reduction in battery life can be up to around 6% at 164 dB MCL and up to around 17% at 144 dB MCL depending on the UL reporting interval, packet size, and RRC procedure. Similar observations can be made from ANNEX A in MediaTek contribution where the reduction in battery life can be around 2.6 % at 164 dB MCL and around 11.7% at 144 dB MCL with similar assumptions.

|  |  |  |
| --- | --- | --- |
| GNSS TTFF (hot start 1s), 2h report | | |
| Source | MediaTek  MCL=154 dB, 50 bytes UL, 238 ms report, GNSS 37 mW | Ericsson  MCL=154 dB, 50 bytes UL EDT, 238 ms report, GNSS 37 mW |
| Total active IoT Rx time | 371 ms | - |
| Total active IoT Tx time | 335 ms | - |
| Battery life (TN, years) | 10.5 years | 14.6 years |
| Battery life (NTN, years) | 9.5 years | 12.9 years |
| Reduction in battery life | 9.5 % | 11.6 % |

|  |  |  |
| --- | --- | --- |
| GNSS TTFF (warm start 5s), 24h report | | |
| Source | MediaTek  MCL=154 dB, 50 bytes UL, 238 ms report, GNSS 37 mW | Ericsson  MCL=154 dB, 50 bytes UL EDT, 238 ms report, GNSS 37 mW |
| Total active IoT Rx time | 371 ms | - |
| Total active IoT Tx time | 335 ms | - |
| Battery life (TN, years) | 31.2 years | 33.8 years |
| Battery life (NTN, years) | 27.9 years | 30.0 years |
| Reduction in battery life | 10.2 % | 11.2 % |

Power consumption—short, sporadic connections

Qualcomm considered case IoT UE transmit its payload once every hrs, once every hrs, etc; after transmitting the payload, the UE’s connection is released, and it goes back into deep sleep mode, until before the next transmission occasion. GNSS TTFF assumption is 2s. A typical NB-IoT over NTN scenario (e.g., a good coverage LEO satellite setting for Set 2) corresponding to a downlink SNR (for 15 kHz 1 PRB reception) of 0 dB and an uplink SNR (for 15 kHz 1 PRB transmission) of -5 dB (with a PC5 UE transmitting at the max. power of 20 dBm).



Figure 3: Short, sporadic transmissions for IoT over NTN.

**Under the studied scenario of short, sporadic connections, a GNSS fix before every connection consumes approximately of the UE’s total available energy.**

For UEs that are *mobile*, e.g., say tracking devices, etc., that are operating in this *short, sporadic connection* paradigm, this power penalty due to GNSS cannot be mitigated significantly, under the purview of Release 17 assumptions of GNSS-based uplink pre-compensation. However, for UEs that are *fixed*, e.g., smart meters, etc, these UEs may be able to save power by having a much more relaxed (e.g., once a week, or once a month, depending on the setting) GNSS fixing schedule.

Power consumption—long connections (e.g., based on CDRX)

Qualcomm considered case *long connection* according. The IoT UE may remain in connected mode for a significantly longer duration of time than the short, sporadic connections described above. These may be facilitated e.g., via connected mode DRX (CDRX), wherein much larger payloads are transmitted or received by the UE during the longer connection. 

Figure 4: Long connection with connected mode DRX for IoT over NTN.

A GNSS fix before every uplink transmission occasion (which, in the absence of other mechanisms, may end up being required to maintain uplink synchronization accuracy within specified limits) results in  **of the UE’s total power consumption resulting from GNSS fixes**. While we can mitigate this somewhat for fixed UEs, for mobile UEs (especially UEs moving at high speeds), without other enhancements to connected mode synchronization, we may not be able to avoid this hit to the UE’s power consumption on account of GNSS fixes.

**Under the studied scenario of a long connection employing connected mode DRX (with a DRX cycle of ), a GNSS fix before every uplink transmission consumes approximately of the UE’s total available energy without additional enhancements w.r.t uplink synchronization. This is especially true for mobile UEs that cannot depend on a prior acquired GNSS fix.**

Other observations from power consumption evaluation:

MediaTek observed a general trend with smallest battery life reduction in the order of 1% to 3% when battery life is in the order of 1 year; and largest battery life reduction in the order of 30% to 68% when battery life is in the order of 10 years or longer. GNSS TTFF hot start 1s, 2s and warm start 5s, 30s were simulated.

Ericsson observed that the reduction in battery life can be up to around 6% at 164 dB MCL and up to around 17% at 144 dB MCL depending on the UL reporting interval, packet size, and RRC procedure.

MediaTek observed that in scenarios of fixed IoT Sensors, or GNSS position available in Application Layer for Asset tracking / Fleet management, the impact on battery life is 0 %. There is either no need for UE to get a GNSS position fix (because the UE is fixed position with GNSS position acquired only once during fitting) or the GNSS position is available in the application layer because the UE needs to include it in the report.

CATT observed over 1 year battery life with transmission every 2hr of 200B, and over 2 years battery life with transmission every 2hr of 50B (on 216 mW), and over 10 years with transmission every day of 50B or 200B on 20mw GNSS power consumption of integrated architecture.

Nokia observed GNSS measurement may cause for packet size 50byte case, battery life reduction as 2.33% if 1s hot-start GNSS measurement assumed and 10.66% if 5s warm-start GNSS measurement assumed. While for 200bytes case, reduction will be 1.1% and 5.29% separately for hot-start and warm-start case. More battery life reduction when GNSS start is larger than 5s.

Ericsson proposed RAN1 to discuss and agree on the assumptions for IoT NTN battery life evaluation such as MCL, transmit power, bandwidth and noise figure.

CMCC, APT proposed the study of potential impact of GNSS Position fix on UE power consumption to be de-prioritized.

The following observations are made based on contributing companies:

* Contributing companies have shown consistent observations when using similar assumptions for reporting interval, packet size, GNSS TTFF and power consumption and MCL
* Impact on battery life is 0 % for use case fixed IoT sensors with GNSS position acquired once during fitting, or use case GNSS position available in IoT application Layer for Asset tracking / Fleet management
* In use case where the IoT device is not fixed position and GNSS position in not available in IoT application Layer, the following were observed based on contributing companies:
  + Reduction in battery life is around 6% at 164 dB MCL and around 17% at 144 dB MCL depending on the UL reporting interval, packet size, and RRC procedure with GNSS TTFF hot start 1s and warm start 5s and GNSS power consumption of 37 mW (integrated IoT and GNSS modules).
  + Reduction in battery life is around 1% to 3% when battery life is around 1 year; and 30% to 68% when battery life is around 10 years or longer with GNSS TTFF hot start 1s and warm start 5s and GNSS power consumption of 37 mW (integrated IoT and GNSS modules) and 100 mW (separate IoT and GNSS modules).
  + GNSS measurement may cause for packet size 50byte case, battery life reduction as 2.33% if 1s hot-start GNSS measurement assumed and 10.66% if 5s warm-start GNSS measurement assumed. While for 200bytes case, reduction will be 1.1% and 5.29% separately for hot-start and warm-start case. More battery life reduction when GNSS start is larger than 5s.
  + For short, sporadic connections, a GNSS fix before every connection consumes 34% of the UE’s total available energy; and in long connection employing connected mode DRX (with a DRX cycle of ~10s), a GNSS fix before every uplink transmission consumes 45% of the UE’s total available energy.
  + For long connection employing connected mode DRX (with a DRX cycle of ~10s), a GNSS fix before every uplink transmission consumes approximately 45% of the UE’s total available energy without additional enhancements w.r.t uplink synchronization.
  + Over 1 year battery life with transmission every 2hr of 200B, and over 2 years battery life with transmission every 2hr of 50B (on 216 mW), and over 10 years with transmission every day of 50B or 200B on 20mw GNSS power consumption of integrated architecture.

The battery life evaluation using in Rel-13 TR 45.820 (Section 5.4) has shown that overall the impact of GNSS can be moderate to significant, while allowing battery life of several years in case of significant reduction. The results would suggest that mitigation of power consumption due to GNSS could be a promising area of research that would be beneficial in case of high battery life comparable with cellular IoT of 10 years or beyond would be target for NTN IoT. The evaluation based on contributing companies would suggest the battery life in NTN IoT is sufficient for a working solution in worst case for power consumption where GNSS position fix is assumed to be needed before each UL transmission. In typical IoT applications, the impact on battery life would be 0 % for fixed IoT sensors or GNSS position available in Application Layer.

## Huawei battery life analysis (R1-2102344)

**Table 1. Power consumption with 2 hours report period**

|  |  |  |  |
| --- | --- | --- | --- |
| **Report, 2hours** | | | |
| **Flow assumptions** | **Duration(ms)/each report** | **Power(mW)** | **Power consumption(mWh)** |
| **GNSS(DL)** | 2000 | 100 | 0.055556 |
| **NPSS(DL)** | 20 | 80 | 0.000444 |
| **NSSS(DL)** | 20 | 80 | 0.000444 |
| **NTN SIB(DL, 256bits)** | 24 | 70 | 0.000467 |
| **MIB-NB(DL)** | 60 | 70 | 0.001167 |
| **Msg1(UL)** | 102.4 | 500 | 0.014222 |
| **NPDCCH(DL)** | 8 | 70 | 0.000156 |
| **Msg2(DL, 56bits)** | 12 | 70 | 0.000233 |
| **Msg3(UL)** | 96 | 500 | 0.013333 |
| **NPDCCH(DL)** | 8 | 70 | 0.000156 |
| **Msg4(DL, 256bits)** | 24 | 70 | 0.000467 |
| **ACK/NACK for Msg4(UL)** | 16 | 500 | 0.002222 |
| **PDCCH(DL)** | 8 | 70 | 0.000156 |
| **Msg5(105bytes)** | 320 | 500 | 0.044444 |
| **Idle** | 30000 | 3 | 0.025000 |
| **Sleep(NTN)** | 7167281.6 | 0.015 | 0.029864 |
| **Sleep(TN)** | 7169305.6 | 0.015 | 0.029872 |
| **Total (TN, mWh)** | 0.132317 | | |
| **Total (NTN,mWH)** | 0.188330 | | |
| **Battery(Wh)** | 5.000000 | | |
| **Battery lifte**  **(TN, year)** | 8.627436 | | |
| **Battery lifte**  **(NTN, year)** | 6.061437 | | |

**Table 2. Power consumption with 6 hours report period**

|  |  |  |  |
| --- | --- | --- | --- |
| **Report, 6hours** | | | |
| **Flow assumptions** | **Duration(ms)/each report** | **Power(mW)** | **Power consumption(mWh)** |
| **GNSS(DL)** | 5000 | 100 | 0.138889 |
| **NPSS(DL)** | 20 | 80 | 0.000444 |
| **NSSS(DL)** | 20 | 80 | 0.000444 |
| **NTN SIB(DL, 256bits)** | 24 | 70 | 0.000467 |
| **MIB-NB(DL)** | 60 | 70 | 0.001167 |
| **Msg1(UL)** | 102.4 | 500 | 0.014222 |
| **NPDCCH(DL)** | 8 | 70 | 0.000156 |
| **Msg2(DL, 56bits)** | 12 | 70 | 0.000233 |
| **Msg3(UL)** | 96 | 500 | 0.013333 |
| **NPDCCH(DL)** | 8 | 70 | 0.000156 |
| **Msg4(DL, 256bits)** | 24 | 70 | 0.000467 |
| **ACK/NACK for Msg4(UL)** | 16 | 500 | 0.002222 |
| **PDCCH(DL)** | 8 | 70 | 0.000156 |
| **Msg5(105bytes)** | 320 | 500 | 0.044444 |
| **Idle** | 30000 | 3 | 0.025000 |
| **Sleep(NTN)** | 21564281.6 | 0.015 | 0.089851 |
| **Sleep(TN)** | 21569305.6 | 0.015 | 0.089872 |
| **Total (TN, mWh)** | 0.192317 | | |
| **Total (NTN,mWH)** | 0.331651 | | |
| **Battery(Wh)** | 5.000000 | | |
| **Battery lifte**  **(TN, year)** | 17.807399 | | |
| **Battery lifte**  **(NTN, year)** | 10.326083 | | |

**Table 3. Power consumption with 6 hours report period**

|  |  |  |  |
| --- | --- | --- | --- |
| **Report, 12hours** | | | |
| **Flow assumptions** | **Duration(ms)/each report** | **Power(mW)** | **Power consumption(mWh)** |
| **GNSS(DL)** | 5000 | 100 | 0.13889 |
| **NPSS(DL)** | 20 | 80 | 0.00044 |
| **NSSS(DL)** | 20 | 80 | 0.00044 |
| **NTN SIB(DL, 256bits)** | 24 | 70 | 0.00047 |
| **MIB-NB(DL)** | 60 | 70 | 0.00117 |
| **Msg1(UL)** | 102.4 | 500 | 0.01422 |
| **NPDCCH(DL)** | 8 | 70 | 0.00016 |
| **Msg2(DL, 56bits)** | 12 | 70 | 0.00023 |
| **Msg3(UL)** | 96 | 500 | 0.01333 |
| **NPDCCH(DL)** | 8 | 70 | 0.00016 |
| **Msg4(DL, 256bits)** | 24 | 70 | 0.00047 |
| **ACK/NACK for Msg4(UL)** | 16 | 500 | 0.00222 |
| **PDCCH(DL)** | 8 | 70 | 0.00016 |
| **Msg5(105bytes)** | 320 | 500 | 0.04444 |
| **Idle** | 30000 | 3 | 0.02500 |
| **Sleep(NTN)** | 43164281.6 | 0.015 | 0.17985 |
| **Sleep(TN)** | 43169305.6 | 0.015 | 0.17987 |
| **Total (TN, mWh)** | 0.282317 | | |
| **Total (NTN,mWH)** | 0.421651 | | |
| **Battery(Wh)** | 5.000000 | | |
| **Battery lifte**  **(TN, year)** | 24.261118 | | |
| **Battery lifte**  **(NTN, year)** | 16.244032 | | |

## CATT battery life analysis (R1-2102618)

Table 5 The operation assumptions of protocol flow and GNSS for IoT NTN

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Battery capacity(Wh)** | **5** | **MCL 154dBm** | | **MCL 164dBm** | |
| **Protocol flow assumptions** | **Power(mW)** | **Duration(ms)/each report** | **Power consumption(mWh)** | **Duration(ms)/each report** | **Power consumption(mWh)** |
| **GNSS signal reception** | X | Y | X\*Y/36e5 | Y | X\*Y/36e5 |
| **NPSCH(DL)** | 80 | 291 | 0.006467 | 445 | 0.009889 |
| **NPBCH(DL)** | 70 | 10 | 0.000194 | 30 | 0.000583 |
| **NPRACH(UL)** | 500 | 40 | 0.005556 | 320 | 0.044444 |
| **NPDCCH(DL)** | 70 | 30 | 0.000583 | 220 | 0.004278 |
| **NPUSCH(UL, 50bytes)** | 500 | 320 | 0.044444 | 1920 | 0.266667 |
| **NPUSCH(UL, 200bytes)** | 500 | 960 | 0.133333 | 3840 | 0.533333 |
| **NPDCCH(DL)** | 70 | 30 | 0.000583 | 220 | 0.004278 |
| **NPDCCH(DL)** | 70 | 30 | 0.000583 | 220 | 0.004278 |
| **NPDSCH(DL)** | 70 | 100 | 0.001944 | 800 | 0.015556 |
| **NPUSCH(UL)** | 500 | 40 | 0.005556 | 320 | 0.044444 |
| **NPDCCH(DL)** | 70 | 30 | 0.000583 | 220 | 0.004278 |
| **NPDCCH(DL, monitor)** | 70 | 120 | 0.002333 | 880 | 0.017111 |
| **idle** | 3 | 11040 | 0.009200 | 60595 | 0.050496 |
| **Standby(50bytes,2 hr)** | 0.015 | 7137919 | 0.029741 | 7083810 | 0.029516 |
| **Standby(200bytes,2 hr)** | 0.015 | 7137279 | 0.029739 | 7081890 | 0.029508 |
| **Standby(50bytes,24 hr)** | 0.015 | 86337919 | 0.359741 | 86283810 | 0.359516 |
| **Standby(200bytes,24 hr)** | 0.015 | 86337279 | 0.359739 | 86281890 | 0.359508 |

Table 6 The battery life with and without GNSS reception

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **power(mw)/duration(s)**  **Packet size, reporting interval,MCL** | **Battery life (years)** | | | | | | | | | | |
| **no GNSS** | **20mw/5s** | **20mw/10s** | **20mw/20s** | **20mw/40s** | **20mw/50s** | **216mw/5s** | **216mw/10s** | **216mw/20s** | **216mw/40s** | **216mw/50s** |
| **50bytes,2 hrs,MCL154** | 10.6 | 8.4 | 7.0 | 5.2 | 3.5 | 3.0 | 2.8 | 1.6 | 0.9 | 0.5 | 0.4 |
| **200bytes,2 hrs,MCL154** | 5.8 | 5.1 | 4.5 | 3.7 | 2.7 | 2.4 | 2.3 | 1.4 | 0.8 | 0.4 | 0.4 |
| **50bytes,24 hrs,MCL154** | 31.3 | 29.4 | 27.8 | 25.0 | 20.8 | 19.1 | 18.6 | 13.2 | 8.4 | 4.8 | 4.0 |
| **200bytes,24 hrs,MCL154** | 26.0 | 24.7 | 23.5 | 21.5 | 18.3 | 17.0 | 16.6 | 12.2 | 7.9 | 4.7 | 3.9 |
| **50bytes,2 hrs,MCL164** | 2.3 | 2.2 | 2.1 | 1.9 | 1.6 | 1.5 | 1.4 | 1.0 | 0.7 | 0.4 | 0.3 |
| **200bytes,2 hrs,MCL164** | 1.5 | 1.4 | 1.4 | 1.3 | 1.2 | 1.1 | 1.1 | 0.8 | 0.6 | 0.4 | 0.3 |
| **50bytes,24 hrs,MCL164** | 16.6 | 16.0 | 15.5 | 14.6 | 13.1 | 12.4 | 12.2 | 9.6 | 6.8 | 4.2 | 3.6 |
| **200bytes,24 hrs,MCL164** | 12.5 | 12.2 | 11.9 | 11.4 | 10.4 | 10.0 | 9.8 | 8.1 | 6.0 | 3.9 | 3.3 |

Figure 4 battery life with and without GNSS

## Qualcomm battery life analysis (R1-2103071)

Table 1: Parameters for evaluating power consumption in IoT over NTN.

|  |  |  |
| --- | --- | --- |
| Operation | Current  (Referenced to downlink current ) | Duration |
| GNSS reception |  | **ms** |
| Downlink Reception |  | 1. PDCCH:  **ms** 2. PDSCH (RAR):  **ms** 3. PDSCH (Msg4): **ms** 4. PDSCH (Conn. Release):  **ms** |
| Uplink Transmission |  | 1. PRACH:  **ms** 2. Msg3:  **ms** 3. PUSCH (data):  **ms per ~ bits**   (*simulated with 8000 bits per ON-duration*)   1. HARQ-ACK:  **ms** |
| Sleep |  | 1. PSM: **8 hrs** 2. CDRX: |



Figure 3: Short, sporadic transmissions for IoT over NTN.

**Under the studied scenario of short, sporadic connections, a GNSS fix before every connection consumes approximately of the UE’s total available energy.**



Figure 4: Long connection with connected mode DRX for IoT over NTN.

**Under the studied scenario of a long connection employing connected mode DRX (with a DRX cycle of ), a GNSS fix before every uplink transmission consumes approximately of the UE’s total available energy without additional enhancements w.r.t uplink synchronization.**

## MediaTek battery life analysis (R1-2102755)







|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| EVERY 2 HOUR (GNSS TTFF HOT START + NTN SIB 16B Reading) | | | | | | | |
|  |  | **50 BYTES** | | | **200 BYTES** | | |
| **GNSS TTFF** | **MCL** | **CIoT** | **Integrated** | **Module** | **CioT** | **Integrated** | **Module** |
| 0 s | 144 dB | 18.73 | | | 17.35 | | |
| 154 dB | 10.51 | | | 5.43 | | |
| 164 dB | 2.68 | | | 1.27 | | |
| 1 s | 144 dB | 18.73 | 15.8 | 12.72 | 17.35 | 14.81 | 12.07 |
| 154 dB | 10.51 | 9.52 | 8.31 | 5.43 | 5.16 | 4.78 |
| 164 dB | 2.68 | 2.61 | 2.51 | 1.27 | 1.26 | 1.23 |
| 2 s | 144 dB | 18.73 | 13.84 | 9.71 | 17.35 | 13.07 | 9.33 |
| 154 dB | 10.51 | 8.77 | 6.91 | 5.43 | 4.93 | 4.28 |
| 164 dB | 2.68 | 2.55 | 2.37 | 1.27 | 1.24 | 1.2 |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| EVERY DAY (GNSS TTFF WARM START + NTN SIB 16B Reading) | | | | | | | |
|  |  | **50 BYTES** | | | **200 BYTES** | | |
| **GNSS TTFF** | **MCL** | **CIoT** | **Integrated** | **Module** | **CioT** | 1. **Integrated** | 1. **Module** |
| 0 s | 144 dB | 35.04 | | | 34.61 | | |
| 154 dB | 31.23 | | | 25.36 | | |
| 164 dB | 18.12 | | | 11.16 | | |
| 5 s | 144 dB | 35.04 | 30.9 | 23.81 | 34.61 | 19.56 | 11.18 |
| 154 dB | 31.23 | 27.9 | 23.68 | 25.36 | 18.32 | 10.76 |
| 164 dB | 18.12 | 16.95 | 15.29 | 11.16 | 12.86 | 8.61 |
| 30 s | 144 dB | 35.04 | 30.56 | 25.57 | 34.61 | 19.43 | 11.14 |
| 154 dB | 31.23 | 23.12 | 20.14 | 25.36 | 16.13 | 9.57 |
| 164 dB | 18.12 | 10.7 | 10.02 | 11.16 | 8.91 | 6.64 |

## Ericsson battery life analysis (R1-2103061)



Figure 1 NB-IoT RRC Resume procedure with UL and DL data transmissions.



Figure 2 NB-IoT EDT procedure with UL data transmission.

Table 1 GNSS parameters for battery life evaluation.

|  |  |  |
| --- | --- | --- |
|  | GNSS TTFF  (sec) | Power consumption  (mW) |
| Hot start | 1 | 37 |
| Warm start | 5 | 37 |

Table 2 eMTC and NB-IoT power consumption for battery life evaluation.

|  |  |
| --- | --- |
| Mode | Power consumption (mW) |
| TX | 545 |
| RX | 90 |
| RRC Connected | 3 |
| RRC Idle | 0.015 |

Table 3 eMTC battery life with 200 bytes UL data and 50 bytes DL data for various values of MCL and UL reporting interval.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMTC, 200 bytes UL, 50 bytes DL | | Battery life TN (year) | Battery life NTN (year) | Change (%) | Battery life TN (year) | Battery life NTN (year) | Change (%) | Battery life TN (year) | Battery life NTN (year) | Change (%) |
| MCL (dB) | | 164 | | | 154 | | | 144 | | |
| 2 hr | EDT | 1.0 | 1.0 | ~0 | 8.8 | 8.2 | 6.82 | 22 | 18.4 | 16.36 |
| 2 hr | RRC Resume | 0.9 | 0.9 | ~0 | 8.2 | 7.6 | 7.32 | 22 | 18.4 | 16.36 |
| 24 hr | EDT | 9.1 | 9.1 | ~0 | 30.0 | 27.0 | 10.0 | 37.0 | 32.5 | 12.16 |
| 24 hr | RRC Resume | 8.4 | 8.4 | ~0 | 29.4 | 26.5 | 9.86 | 37.0 | 32.5 | 12.16 |

Table 4 eMTC battery life with 50 bytes UL data and 50 bytes DL data for various values of MCL and UL reporting interval.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMTC, 50 bytes UL, 50 bytes DL | | Battery life TN (year) | Battery life NTN (year) | Change (%) | Battery life TN (year) | Battery life NTN (year) | Change (%) | Battery life TN (year) | Battery life NTN (year) | Change (%) |
| MCL (dB) | | 164 | | | 154 | | | 144 | | |
| 2 hr | EDT | 2.6 | 2.5 | 3.85 | 14.6 | 12.9 | 11.64 | 23.4 | 19.4 | 17.09 |
| 2 hr | RRC Resume | 2.0 | 2.0 | ~0 | 13.2 | 11.8 | 10.61 | 23.5 | 19.4 | 17.45 |
| 24 hr | EDT | 17.9 | 16.8 | 6.14 | 33.8 | 30.0 | 11.24 | 36.3 | 32.1 | 11.57 |
| 24 hr | RRC Resume | 15.4 | 14.5 | 5.84 | 33.1 | 29.5 | 10.88 | 36.4 | 32.1 | 11.81 |

Table 5 NB-IoT battery life with 200 bytes UL data and 50 bytes DL data for various values of MCL and UL reporting interval.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| NB-IoT, 200 bytes UL, 50 bytes DL | | Battery life TN (year) | Battery life NTN (year) | Change (%) | Battery life TN (year) | Battery life NTN (year) | Change (%) | Battery life TN (year) | Battery life NTN (year) | Change (%) |
| MCL (dB) | | 164 | | | 154 | | | 144 | | |
| 2 hr | EDT | 1.4 | 1.4 | ~0 | 7.9 | 7.3 | 7.59 | 19.8 | 16.9 | 14.65 |
| 2 hr | RRC Resume | 1.1 | 1.1 | ~0 | 7.4 | 7.0 | 5.41 | 19.3 | 16.5 | 14.51 |
| 24 hr | EDT | 11.4 | 11.4 | ~0 | 29.0 | 26.2 | 9.65 | 36.4 | 32.1 | 11.81 |
| 24 hr | RRC Resume | 9.7 | 9.7 | ~0 | 28.5 | 25.7 | 9.82 | 36.3 | 31.9 | 12.12 |

Table 6 NB-IoT battery life with 50 bytes UL data and 50 bytes DL data for various values of MCL and UL reporting interval.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| NB-IoT, 50 bytes UL, 50 bytes DL | | Battery life TN (year) | Battery life NTN (year) | Change (%) | Battery life TN (year) | Battery life NTN (year) | Change (%) | Battery life TN (year) | Battery life NTN (year) | Change (%) |
| MCL (dB) | | 164 | | | 154 | | | 144 | | |
| 2 hr | EDT | 3.4 | 3.3 | 2.94 | 13.4 | 12.0 | 10.45 | 22.2 | 18.5 | 16.67 |
| 2 hr | RRC Resume | 2.6 | 2.5 | 3.85 | 12.4 | 11.2 | 9.67 | 21.6 | 18.1 | 16.20 |
| 24 hr | EDT | 20.5 | 19.1 | 6.83 | 33.2 | 29.6 | 10.84 | 36.2 | 31.9 | 11.88 |
| 24 hr | RRC Resume | 17.8 | 16.7 | 6.18 | 32.7 | 29.1 | 11.01 | 36.0 | 31.8 | 11.67 |

## Nokia battery life analysis (R1-210832)

In first step, GNSS measurement by UE are assumed to be ideally accurate (although there may be some issue as analysis above), then considering 50Bytes and 200Bytes packet, reporting (data) interval as 2hour or 1day, battery life reduction because of GNSS related power consumption will be as in Figure 1, where we assume a hot start >=1s and warm start >=5s and with other assumption as Table 2&3 aligned with [R1-157251, Nokia Networks, “NB IoT – Battery lifetime evaluation in standalone operation”, 3GPP RAN1 #83]. Annex A Table 4&5 provide the original results.

**Table 2 Assumption for requested time for each item in Tx/Rx**

|  |  |  |
| --- | --- | --- |
| Activity | State | ms |
| Synchronization | RX | 215 |
| MIB acquisition | Rx | 64 |
| Idle | 576 |
| PRACH | Tx | 160 |
| Idle | 640 |
| DCI + RAR | Rx | 72 |
| Msg3 | Tx | 340 |
| DCI + Msg4 | Rx | 72 |
| DCI (UL grant) | Rx | 36 |
| Report (50 bytes) | Tx | 1405 |
| Report (200 bytes) | Tx | 4648 |
| HARQ ACK | Rx | 36 |
| DCI | Rx | 36 |
| IP Ack | Rx | 200 |
| HARQ ACK | Tx | 288 |
| PDCCH monitoring | Rx | 1440 |
| Extra wait time | Idle | 22000 |

**Table 3 Assumption for battery capacity and battery power consumption**

|  |  |
| --- | --- |
| Battery capacity (Wh) | 5 |
| Battery power during Tx (mW) | 543 |
| Battery power for Rx (mW) | 90 |
| Battery power when Idle but not in PSS (mW) | 2.4 |
| Battery power in Power Save State (PSS) (mW) | 0.015 |
| battery power for GNSS Rx (mW) | **37** |

**Table 4 battery life reduction because of GNSS measurement**



**Figure 1 battery life reduction because of GNSS measuerement**

Another points that will reduce battery life for IoT over NTN is SIB reading for satellite ephemeris. If assuming power consumption for SIB reading is 90mW, then battery life reduction will be as in Figure 2.



**Figure 2 battery life reduction because of SIB reading for satellite ephemeris (90mW)**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| packet size = 50Bytes |  | Reporting  interval (hour) | Number of reports per day | Rx time of GNSS measurement (ms) | Reduced battery life (%) |  | Reporting  interval (hour) | Number of reports per day | Rx time of GNSS measurement (ms) | Reduced battery life (%) |
|  |  | 2 | 12 | 1000 | 2.332 |  | 24 | 1 | 5000 | 6.329 |
|  |  | 2 | 12 | 2000 | 4.557 |  | 24 | 1 | 10000 | 11.905 |
|  |  | 2 | 12 | 3000 | 6.683 |  | 24 | 1 | 15000 | 16.854 |
|  |  | 2 | 12 | 4000 | 8.717 |  | 24 | 1 | 20000 | 21.277 |
|  |  | 2 | 12 | 5000 | 10.663 |  | 24 | 1 | 25000 | 25.253 |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
| packet size = 200Bytes |  | Reporting  interval (hour) | Number of reports per day | Rx time of GNSS measurement (ms) | Reduced battery life (%) |  | Reporting  interval (hour) | Number of reports per day | Rx time of GNSS measurement (ms) | Reduced battery life (%) |
|  |  | 2 | 12 | 1000 | 1.105 |  | 24 | 1 | 5000 | 3.950 |
|  |  | 2 | 12 | 2000 | 2.186 |  | 24 | 1 | 10000 | 7.599 |
|  |  | 2 | 12 | 3000 | 3.244 |  | 24 | 1 | 15000 | 10.982 |
|  |  | 2 | 12 | 4000 | 4.279 |  | 24 | 1 | 20000 | 14.125 |
|  |  | 2 | 12 | 5000 | 5.292 |  | 24 | 1 | 25000 | 17.054 |

**Table 5 battery life reduction because of SIB reading for satellite ephemeris**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| packet size = 50Bytes |  | Reporting  interval (hour) | Number of reports per day | Rx time of NTN SIB (ms) | Reduced battery life (%) |  | Reporting  interval (hour) | Number of reports per day | Rx time of NTN SIB (ms) | Reduced battery life (%) |
|  |  | 2 | 12 | 20 | 0.116 |  | 24 | 1 | 20 | 0.066 |
|  |  | 2 | 12 | 30 | 0.174 |  | 24 | 1 | 30 | 0.099 |
|  |  | 2 | 12 | 40 | 0.232 |  | 24 | 1 | 40 | 0.131 |
|  |  | 2 | 12 | 50 | 0.289 |  | 24 | 1 | 50 | 0.164 |
|  |  | 2 | 12 | 60 | 0.347 |  | 24 | 1 | 60 | 0.197 |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
| packet size = 200Bytes |  | Reporting  interval (hour) | Number of reports per day | Rx time of NTN SIB (ms) | Reduced battery life (%) |  | Reporting  interval (hour) | Number of reports per day | Rx time of NTN SIB (ms) | Reduced battery life (%) |
|  |  | 2 | 12 | 20 | 0.054 |  | 24 | 1 | 20 | 0.040 |
|  |  | 2 | 12 | 30 | 0.081 |  | 24 | 1 | 30 | 0.060 |
|  |  | 2 | 12 | 40 | 0.109 |  | 24 | 1 | 40 | 0.080 |
|  |  | 2 | 12 | 50 | 0.136 |  | 24 | 1 | 50 | 0.100 |
|  |  | 2 | 12 | 60 | 0.163 |  | 24 | 1 | 60 | 0.120 |

# Appendix B

|  |  |
| --- | --- |
| Contribution | Observation/Proposals |
| Huawei (R1-2102344) | ***Observation 1:*** *There will be a large timing drift in case of large number of repetitions for preamble transmission.*  ***Observation 2:*** *There will be**a large timing drift in case of 256ms time-contiguous transmission for NPUSCH.*  ***Observation 3:*** *Decoding system information or receiving closed loop TAC command for TA adjustment during UL repetition will introduce extra power consumption for IoT devices.*  ***Observation 4:*** *RACH failure may happen for an NB-IoT UE since it may stay in the cell for a short time, which leads to* *increased power consumption.*  ***Observation 5:*** *Power consumption of GNSS and NTN related SIB reading have a large impact to battery life of IoT devices.*  ***Observation 6:*** *The differential frequency shift in IoT over NTN may become larger than the existing channel raster in some deployment.*  ***Proposal 1:*** *An IoT-NTN UE at least supports TA calculation based on common TA indication and a UE specific TA.*  ***Proposal 2:*** *UE autonomous TA adjustment should be applied during the long preamble transmission duration to compensate the large timing drift.*  ***Proposal 3:*** *More UL gaps should be inserted according to the maximum allowed time-continuous transmission for IoT over NTN.*  ***Proposal 4:*** *Using TA drift rate to calculate and compensate the TA drift for UL transmission with long duration.*  ***Proposal 5:*** *The indication of DL frequency pre-compensation is normalized to a predefine subcarrier spacing.*  ***Proposal 6:*** *To reduce the signaling overhead, only DL pre-compensation indication is needed and sufficient for UL frequency alignment.* |
| OPPO (R1-2102423) | **Proposal 1**: a GNSS measurement window is needed and the network/UE have to have a common understanding on the GNSS window.  **Proposal 2**: Study whether the DL and UL gap shall take into account NTN-SIB reading.  **Proposal 3**: Study whether and how the UL gap should be enhanced, considering the NTN timing drift rate and frequency drift rate.  **Proposal 4**: PRACH transmission back-off can be beneficial to resolve the issue of PRACH congestion. |
| Spreadtrum (R1-2102473) | **Proposal 1**: UL timing compensation mechansim in RRC\_IDLE and RRC\_INACTIVE states of NTN WI can be reused in IoT NTN.  **Proposal 2**: UL timing compensation mechansim for RRC\_ CONNECED states UEs of NTN WI can be reused in IoT NTN.  **Proposal 3**: Reference point for autonomous acquisition of the TA at UE is located at the satellite.  **Proposal 4**: Both open and closed control loops are supported in connected mode for IOT NTN.  **Proposal 5**: Reuse frequency compensation mechanism of NTN WI in IoT NTN.  **Proposal 6**: In IOT NTN, the reference point for frequency synchronization is located at the satellite.  **Proposal 7**: Updates on the pre-compensation value of time delay and frequency offset during the repetitions should be considered in UL transmission.  **Proposal 8**: Enhancement on transmission gap in existing specifications can be considered for time-frequency offset adjustments in once transmission time interval. |
| CATT (R1-2102618) | **Observation 1**: UE may have the maximum initial frequency error more than 50KHz contributed by oscillator, Doppler shift and anchor carrier offset in S band.  **Observation 2**: Except format 4, preamble format needn’t be enhanced for GNSS-capable UE.  **Observation 3**: Over 1 year battery life with transmission every 2hr of 200B, and over 2 years battery life with transmission every 2hr of 50B, and over 10 years with transmission every day of 50B or 200B on 20mw GNSS power consumption of integrated architecture.  **Observation 4**: The impact on battery life of NTN SIB1 reading to acquire satellite ephemeris for UE pre-compensation is negligible.  **Observation 5**: A large amount of UEs are linked to same PRACH occasion after reading SIB1, which probably causes PRACH congestion.  **Proposal 1**: Increasing channel raster in IoT NTN is necessary.  **Proposal 2**: Reuse timing and frequency compensation mechanism of NR NTN to IoT NTN by taking into account UE power assumption.  **Proposal 3**: Defining specific requirement on synchronization accuracy for IoT NTN is needed.  **Proposal 4**: Consider resource isolation for different users in UL signal transmission to guarantee UL transmission performance of NTN NB-IoT.: RAN1 needs to study if Preamble format 4 is supported for NTN eMTC due to higher timing accuracy requirement.  **Proposal 6**: Study suitable interval for TA compensation updating during long PRACH repetition transmission.  **Proposal 7**: Consider dropping tail samples of a slot or inserting a gap before signal transmission for TA variation during long (N)PUSCH repetition transmission.  **Proposal 8**: Study suitable interval for frequency compensation updating during long PRACH and (N)PUSCH repetition transmission.  **Proposal 9**: Study the mechanism to trigger GNSS measurement when UE initiates the wakeup from PSM state or inactive state of eDRX.  **Proposal 10**: In view of technical development, 20~30mW power consumption for GNSS reception could be considered.  **Proposal 11**: Further to enhance on the selection of PRACH occasion in the initial access. |
| Asia Pacific Telecom (R1-2102736) | **Observation 1**: For long transmission on NPUSCH more than 256ms, simply up to UE pre-compensation cannot prevent a signal overlap within 256ms.  **Observation 2** : For long transmission on NPUSCH more than 256ms, limiting NPUSCH transmission less than 256ms cannot satisfy a need of up to 128 repetitions on NPUSCH.  **Observation 3** : NPRACH transmission supports 40ms of UCG after transmission of 256ms. In 256ms, the total drift is around 6.4 us that can be supported by the NRACH preambles.  **Proposal 1** : Deprioritize the following study agreed in RAN#104-e: 1) impact of GNSS Position fix; 2) GNSS measurement window; 3) NTN SIB carrying the satellite ephemeris.  **Proposal 2** : UCG shall be configurable to accommodate different NTN scenarios, e.g., after transmissions of X time units for NPUSCH, a gap of Y time units shall be inserted, if X and Y are provided by NW.  **Proposal 3** : For long transmission on PRACH, no enhancement is needed, and reusing the legacy 40ms of UCG for NPRACH transmission shall be considered. |
| MediaTek (R1-2102755) | ***Observation 1****: Assuming UE stays in connected for a duration of 10 s to transmit an intermittent delay tolerant small packet, the UE can accurately predict and pre-compensate the satellite delay and Doppler shift while transmitting the long PUSCH without need to re-acquire GNSS location.*  ***Proposal 1****: UE pre-compensate satellite delay and Doppler shift during long UL transmission on PUSCH in NB-IoT and eMTC.*  ***Observation 2****: The legacy UL compensation gap is 40 ms is sufficient to re-acquire DL synchronization for interrupted long UL synchronization providing a solution is specified to accommodate the high satellite Doppler shift of ±42 kHz in addition the device crystal error of ±20 ppm (about ±40 kHz at Fc=2 GHz).*  ***Proposal 2****: Re-use the legacy UL Compensation Gap of 40 ms for IoT NTN*  ***Observation 3****: Assuming UE initiates random access procedure to transmit an intermittent delay tolerant small packet within 10 seconds latency requirement in Rel-13 CIoT, the UE can pre-compensate the satellite delay and Doppler shift while transmitting the long PRACH without need to re-acquire GNSS location.*  ***Proposal 3****: UE pre-compensate satellite delay and Doppler shift during long UL transmission on PRACH in NB-IoT and eMTC.*  ***Observation 4****: It is sufficient to re-use legacy paging and DRX procedures for UE acquisition of GNSS position fix assuming simultaneous GNSS and NTN NB-IoT/eMTC operation is not used in the device*   * *Re-use legacy paging procedure with adequate configuration of paging timer for mobile-terminated calls* * *For idle UE, GNSS measurement for position fix can be done in idle DRX / eDRX / PSM with a GNSS TTFF with hot start or warm start before moving to connected for mobile-originated calls* * *For connected UE, GNSS measurement for position fix can be done in connected DRX / eDRX with a GNSS TTFF with hot start.*   ***Observation 5****: A UE may only need a new GNSS position solely for UE pre-compensation for UL synchronization in corner case scenarios where (i) it is not fixed; (ii) reporting of the GNSS position is not needed by application layer.*  ***Proposal 4****: It is up to UE implementation when to switch on its GNSS module to acquire its position when a new position fix is needed during idle DRX / eDRX / PSM before moving to connected for mobile-terminated calls*  ***Proposal 5****: It is up to UE implementation when to switch on its GNSS module to acquire its position when a new position fix is needed during idle DRX / eDRX / PSM before moving to connected for mobile-originated calls*  ***Observation 6****: For battery life analysis, hot start should be assumption if GNSS module is used within 4 hours; warm start should be assumption if GNSS module is used less that once every 4 hours or longer.*  ***Observation 7****: The UE only needs to acquire SIB1 once within System Information update periodicity to know the scheduling of NTN-specific SIB carrying the serving satellite ephemeris position and velocity state vector.*  ***Proposal 6****: To avoid RACH congestion, NTN SIB carrying the ephemeris for the UE prediction and pre-compensation of satellite delay and Doppler shift is broadcast with a low periodicity – e.g. 1 second.*  ***Observation 8****: Evaluation using the battery life impact of GNSS + NTN SIB reading*   * *Smallest battery life reduction when battery life is small (i.e. in the order of 1 year)* * *Largest battery life reduction when battery life is long (i.e. in the order of 10 years)* * *Battery life impact of NTN SIB Reading has max reduction of 1.61%*   ***Observation 9****: A larger beam diameter size and crystal accuracy of up to ±20 ppm may benefit from a new Channel Raster of 200 kHz for NB-IoT and eMTC to support DL synchronization for LEO.*  ***Observation 10****: A larger beam diameter size and crystal accuracy of up to ±20 ppm may benefit from support of DL frequency broadcast as part of the NTN SIB to support DL synchronization for LEO.* |
| Nokia (R1-2102832) | ***Observation 1****: For IoT UE with reduced cost/complexity, GNSS may be not available or not accurate.*  ***Observation 2****: The maximum doppler shift supported by current LTE NB-IoT/eMTC design is much lower than expected doppler shift in NTN scenario.*  ***Observation 3****: If only consider UE automatic pre-compensation, there will be*  *• UL synchronization error for IoT UE in NTN scenario*  *• The syncrhnizaiton error may last for long time with repeeitions and error propagation,*  *• Mis-alignement between UE and eNB and ineffective for UL sync adjustment.*  ***Observation 4****: If GNSS based time synchronization is used for IoT over NTN, the entire cyclic prefix of the random access preamble should be able to cover multipath propagation delay as well as the inaccuracy imposed by the compensation algorithm based on the GNSS information.*  ***Observation 5****: GNSS measurement may cause*  *• For packet size 50byte case, battery life reduction as 2.33% if 1s hot-start GNSS measurement assumed and 10.66% if 5s wart-start GNSS measurement assumed. While for 200bytes case, reduction will be 1.1% and 5.29% separately for hot-start and warm-start case.*  *• More battery life reduction when GNSS start is larger than 5s.*  ***Observation 6****: IoT UE with reduced cost/complexity will request more power, especially when there is the GNSS unaccuracy issue.*  ***Observation 7****: Using referenceTimeInfo-R16 and UE based understanding of GNSS time will suffer less from the satellite movement in terms of timing advance as the reference point is at a static location (the gNB).*  ***Proposal 1****: DL synchronization performance in NTN scenario based on LTE NPBCH/NPSS/NSSS and LTE PBCH/PSS/SSS in NTN scenario should be evaluated before any further study on DL synchronization, like for SSB in Rel-15.*  ***Proposal 2****: Link budget of GNSS for IoT UE in NTN should be evaluated.*  ***Proposal 3****: It should be evaluated whether GNSS based time frequency synchronization could be available or could be accurate for following IoT cases*  *· With reduced number of receiver antenna*  *· With reduced power consumption*  *· Not covered by GNSS satellite*  ***Proposal 4****: How to compensate large doppler shift for IoT UE should be studied, where simplification of IoT UE processing could be considered.*  ***Proposal 5****: RAN1 and RAN4 should select one alternative of reference point to be working assumption and it is preferred that the selection should be also base line for IoT NTN scenario, where eNB as reference point is more closer to existing eNB implementation and standard.*  ***Proposal 6****: In case GNSS accuracy is not accurate enough or not always available, UL random access procedure should be studied, with baseline as NR over NTN solutions but power consumption and complexity/cost reduction should also be considered.*  ***Proposal 7****: It should be evaluated whether GNSS based time frequency synchronization could be accurate for IoT cases.*  ***Proposal 8****: Considering all issues on GNSS accuracy and GNSS fault for IoT UE with reduced antenna number, second synchronization solution should be studied, not based on GNSS or with less dependence on GNSS.*  ***Proposal 9****: If GNSS based time synchronization is used for IoT over NTN, the aggregate contribution of all sources of inaccuracy must not violate the limits imposed by the cyclic prefix of the random access preamble.*  ***Proposal 10****: The GNSS-assisted pre-compensation solution used by the UE shall meet the demands of the preamble format chosen by the operator, i.e., UE must be prepared to fulfil all preamble format requirements.*  ***Proposal 11****: Combination of UE automatic precompensation and network controlled precompensation should be studied and utilized, to provide effective UL synchronization for all type of UE in all IoT NTN scenario, and to provide fast convergance of UL synchronization.*  ***Proposal 12****: To add Table 2/3/4/5 for power consumption on GNSS and SIB reading for satellite ephemeris in TR.*  ***Proposal 13****: A GNSS gap should be configured in paging procedure, where the exact position of the GNSS gap in paging procedure can be further studied.*  ***Proposal 14****: Half duplex for UL, DL and GNSS reception should be studied considering GNSS accuracy and UE capability.*  ***Proposal 15****: Network should be in control of the timing advance updates applied at the UE.*  ***Proposal 16****: If UE is performing autonomous update of timing advance during RRC\_CONNECTED mode, the network should know the details of such adjustments in advance.*  ***Proposal 17****: Self adjustement by the UE based on GNSS time and the time provided by referenceTimeInfo-R16 is a feasible solution and should be standardized as well.*  ***Proposal 18****: TA value changing during the repetitions should be configured, e.g. a bundle of TA and corresponding time to utilize, by Node B for UL transmission in IoT over NTN.* |
| CMCC (R1-2102906) | ***Observation 1:*** GNSS measurement can be done up to UE’s implementation in the preparation period before DRX active duration, and no specification change is needed.  ***Proposal 1:*** There is no need to introduce GNSS measurement window for initial access.  ***Proposal 2:*** The study of potential impact of GNSS Position fix on UE power consumption to be de-prioritized.  ***Proposal 3:*** The study of potential impact of NTN SIB carrying the satellite ephemeris on UE power consumption to be de-prioritized.  ***Proposal 4:*** Regarding accuracy of satellite location tracking, satellite position and velocity state vectors based ephemeris format (128 bits or 144 bits) with high periodicity (e.g. 1s or 2s) can be taken as baseline for discussion.  ***Proposal 5:*** There is no PRACH congestion problem with SIB read.  ***Proposal 6:*** Use UE-specific TA calculation (), which can be calculated based on GNSS-acquired UE position and serving satellite ephemeris, and network indicated common TA () for UE pre-compensation of satellite delay during long UL transmission on (N)PUSCH in NB-IoT and eMTC.  ***Proposal 7:*** Use the doppler shift on the service link, which can be calculated based on GNSS-acquired UE position and serving satellite ephemeris, for UE pre-compensation of satellite doppler shift during long UL transmission on (N)PUSCH in NB-IoT and eMTC.  ***Proposal 8:*** Use UE-specific TA calculation (), which can be calculated based on GNSS-acquired UE position and serving satellite ephemeris, and network indicated common TA () for UE pre-compensation of satellite delay during long UL transmission on PRACH in NB-IoT and eMTC.  ***Proposal 9:*** Use the doppler shift on the service link, which can be calculated based on GNSS-acquired UE position and serving satellite ephemeris, for UE pre-compensation of satellite doppler shift during long UL transmission on PRACH in NB-IoT and eMTC.  ***Proposal 10:*** The study of (N-)PBCH coverage enhancement to be de-prioritized. |
| ZTE (R1-2102917) | ***Observation 1:*** *100 kHz channel raster may not be large enough to avoid ambiguity in DL synchronization of IoT over NTN when multiple cells from different satellites could cover same UE.*  ***Observation 2:*** *The power consumption of SIB reading for ephemeris Option 2 is significantly less than that of the Option 1.*  ***Observation 3:*** *The power consumption of GNSS positioning is much larger than that of the SIB reading for ephemeris Option 2.*  ***Proposal 1:*** *DL synchronization performance should be evaluated for target scenarios.*  ***Proposal 2:*** *Channel raster should be enhanced in IoT over NTN if the scenarios with co-covered cells from different LEO satellites is supported.*  ***Proposal 3:*** *Segmented pre-compensation for long continuous repetition transmission should be considered.*  ***Proposal 4:*** *The time duration of gap between adjacent segments of one UL transmission should be supported.*  ***Proposal 5:*** *A valid time range can be indicated to UE for one TA value applied in one UL transmission.*  ***Proposal 6:*** *When TA report is enabled, TA value of first or last segment of transmission delivering the TA report should be considered.*  ***Proposal 7:*** *Study on the frequency of SIB reading for ephemeris should be considered.*  ***Proposal 8:*** *Study the configuration of time gap for GNSS positioning.*  ***Proposal 9:*** *Study the optimization on power saving when GNSS positioning for every UL transmission is unnecessary.*  ***Proposal 10:*** *Study PRACH format to improve UE density.* |
| Xiaomi (R1-2102973) | ***Observation 1****: Existing NB-IoT/eMTC PRACH formats and preamble sequences can be reused with the assumption UE having GNSS capability.*  ***Observation 2****: Segmented UE pre-compensation of satellite delay is needed during long UL transmission.*  ***Observation 3****: Segmented UE pre-compensation of satellite Doppler shift is not needed.*  ***Proposal 1****: Pre-compensation on the Doppler shift for DL transmission should be supported.*  ***Proposal 2****: Reuse the UL time and frequency synchronization mechanism for IoT NTN in short UL transmission while taking into account the UE power consumption.*  ***Proposal 3****: Use UE-specific TA calculation based on the timing drift rate for UE pre-compensation during long UL transmission.* |
| Intel (R1-2103056) | ***Proposal 1***:   * *Time and frequency offset introduced in service link is pre-compensated by the UE for UL transmission based on UE location (from GNSS) and satellite ephemeris (broadcasted by the gNB)* * *The following options are considered for compensation of time offset introduced in feeder link for UL transmission*   + *Post-compensation at the gNB side*   + *Pre-compensation at the UE side* * *Compensation at the gNB side should be used for frequency offset introduced in feeder link for UL and DL transmission*   ***Proposal 2***:   * *If pre-compensation of time offset introduced in feeder link for UL is used, at least one of the following options should be supported*   + *Broadcasting of common TA and common TA drift rate*   + *Broadcasting of reference point for common TA calculation*   ***Proposal 3***:   * *Enhancements for non-GEO satellite deployment with moving beams and frequency reuse should be discussed assuming existing features of eMTC and NB-IoT (e.g. multi-carrier operation and mobility)*   + *Increased number of anchor carriers for NB-IoT multi-carrier operation* *can be considered*   ***Proposal 4***:   * *Additional gap for DL measurements during long UL transmission is not needed*    + *It is assumed that UE can autonomously update delay and Doppler values based on satellite ephemeris and UE location* * *FFS: whether additional gap during long UL transmission is needed to calculate and apply the updated TA and UL frequency at the UE* |
| Ericsson (R1-2103061) | **Observation 1**: As GNSS-equipped UEs can perform timing/frequency pre-compensation before MSG1 transmission, the existing (N)PRACH formats for NB-IoT/eMTC in TN are also sufficient for NTN scenarios.  **Observation 2**: For eMTC/NB-IoT, the reduction in battery life can be up to around 6% at 164 dB MCL and up to around 17% at 144 dB MCL depending on the UL reporting interval, packet size, and RRC procedure.  **Observation 3**: To have a more nuanced comparison between the battery life for NTN and legacy IoT devices, the underlying simulation assumptions such as transmit power, bandwidth, noise figure, and MCL should be agreed.  **Observation 4**: We need to identify if specification changes are needed to allow the UE to perform UL pre-compensation during a long UL transmission.  **Observation 5**: UE may pre-calculate the timing and frequency pre-compensation values for each anticipated pre-compensation occasion prior to the start of the UL transmission.  **Proposal 1**: UE should pre-compensate its timing and frequency before transmitting MSG1.  **Proposal 2**: As a baseline, the time and frequency synchronization for eMTC and NB-IoT should follow the same principles as outlined in the NR NTN WI.  **Proposal 3**: RAN1 should investigate DL synchronization performance for NB-IoT and eMTC NTN.  **Proposal 4**: RAN1 should discuss whether GNSS positioning in RRC\_CONNECTED state is to be supported by IoT NTN UE.  **Proposal 5**: RAN1 to wait for further progress on this topic in RAN2.  **Proposal 6**: RAN1 to discuss and agree on the assumptions for IoT NTN battery life evaluation such as MCL, transmit power, bandwidth and noise figure.  **Proposal 7**: To accurately evaluate the impact of NTN SIB reads on eMTC/NB-IoT device battery life, RAN1 to discuss and agree on the assumptions for NTN SIB carrying satellite ephemeris such as NTN SIB format, periodicity and MCL.  **Proposal 8**: RAN1 to discuss and agree on the underlying scenario to study the impact of NTN SIB on PRACH congestion. |
| Qualcomm (R1-2103071) | Essential for Release 17  ***Observation E-1***: In S-band frequencies, the frequency error during initial downlink synchronization (initial cell access) can be up to 47.5 kHz + .  ***Proposal E-1*: RAN1 to specify solutions to prevent a UE from locking on to an incorrect frequency corresponding to a Ncell, including:**   * **increasing the raster size** * **including a portion of the ARFCN in the (NB-)MIB.**   ***Proposal E-2***: **Support NB-IoT over NTN in standalone and in-band/guard-band with NR modes only.**  ***Observation E-2***: Under the studied scenario of short, sporadic connections, a GNSS fix before every connection consumes approximately of the UE’s total available energy.  ***Observation E-3***: Under the studied scenario of a long connection employing connected mode DRX (with a DRX cycle of ), a GNSS fix before every uplink transmission consumes approximately of the UE’s total available energy without additional enhancements w.r.t uplink synchronization.   * This is especially true for mobile UEs that cannot depend on a prior acquired GNSS fix   ***Observation E-4***: If a half-duplex UE (i.e., all NB-IoT and some eMTC UEs) is mandated to read the SIB (containing satellite location information) immediately preceding every uplink transmission, this may lead to dropped uplink transmissions.  ***Proposal E-3*: At least for short, sporadic connections, a SIB containing satellite location information is not read in connected mode.**  ***Observation E-5***: An implicit way to limit connection length for eMTC/NB-IoT over NTN is via the definition of synchronization validity.  ***Proposal E-4*: RAN1 to define the notion of synchronization validity during which the ephemeris and/or GNSS information is (are) accurate.**   * **This validity is based on timer(s) that are (re-)set autonomously by the UE after acquiring necessary location information.** * **Such (re-)setting events may be indicated to the network to facilitate efficient scheduling.**   ***Proposal E-5*: RAN1 to introduce a mechanism that triggers RLF when the GNSS and/or ephemeris information at the UE is (are) outdated:**  **- FFS details**  Recommended for inclusion in TR  ***Observation R-1*:** For long connections in eMTC and NB-IoT over NTN, (N)PRACH-driven closed-loop time and frequency corrections lowers the GNSS power penalty from  **to**  (with a GNSS relaxation factor of 4), w.r.t a baseline without closed-loop corrections.   * Such an (N)PRACH-driven closed loop correction may be facilitated by a periodic or semi-persistent CFRA transmission from the UE, followed by a response message from the network. * An NPRACH design that is robust to time and frequency errors (e.g., the one based on restricted preambles in Section 6 of this contribution) is especially suitable for this.   ***Proposal R-1*: Include Observation R-1 in the TR, in the context of current or future study and support of long connections for eMTC and NB-IoT over NTN, as it relates to uplink synchronization aspects.**  ***Proposal R-2*: RAN1 to consider potential enhancements to (N)PRACH design, depending on the requirements for satellite location accuracy and UE’s own geolocation accuracy at the UE.**   * **The design should also consider facilitating closed-loop time and/or frequency corrections.**   ***Observation R-2*:** Restricting alternate starting subcarriers for NPRACH transmissions allows to correct for potentially large initial uplink frequency synchronization errors (e.g., up to 1 kHz)   * Such a scheme may facilitate UE power savings by relaxing the frequency and accuracy of GNSS fixes and/or satellite ephemeris reads required. * Such a scheme may also facilitate NPRACH-driven closed-loop corrections of time and frequency errors in connected mode, thereby reducing the power penalty from frequent GNSS fixes.   ***Proposal R-3*: Include Observation R-2 in the TR, in the context of current or future study for eMTC and NB-IoT over NTN, as it relates to uplink synchronization aspects.**  Useful optimizations  ***Proposal O-1*: Include the first three symbols in a subframe as well as the REs corresponding to the 4 CRS ports for rate matching the NPBCH.**  ***Proposal O-2*: RAN1 to consider non-RLF mechanisms for handling outdated ephemeris/GNSS information including:**   * **UE triggered scheduling gap, prioritizing re-acquiring synchronization, e.g., via reading SIB.** * **Transmission of specially designated (N)PRACH preambles, and reception of corresponding closed-loop correction commands.** * **Other relevant solutions.**   ***Proposal O-3*: RAN1 to consider, in addition to the SIB-based broadcast mode of transmission, a dedicated unicast transmission of satellite location information to UEs.**   * **Such a dedicated transmission may precede an uplink grant, to ensure maintenance and better accuracy of uplink synchronization, and minimize synchronization failure events.** * **An example of the above would be for a DCI that schedules an uplink transmission to also schedule a downlink (N)PDSCH, carrying satellite location information, preceding the uplink grant.** |
| Apple (R1-2103133) | ***Proposal 1:*** *In IoT over NTN, consider that UE pre-compensates a timing advance in PRACH transmission, which is composed of network indicated common timing offset and self-estimated UE specific TA based on its GNSS location and serving satellite ephemeris.*  ***Proposal 2:*** *In IoT over NTN, the GNSS measurement window is needed and beneficial for initial access.*  ***Proposal 3:*** *RAN1 to study the enhancement of the duration of contiguous NPRACH or NPUSCH transmissions without TA update and the uplink compensation gap.*  ***Proposal 4:*** *UE calculates and pre-compensates the Doppler shift on service link based on its GNSS location and serving satellite ephemeris.*  ***Proposal 5:*** *Support network pre-compensates the frequency offset in downlink transmissions.* |
| Samsung (R1-2103267) | **Proposal 1**: TA estimation should be supported for GNSS-capable UE at least for initial access.  **Proposal 2**: Common TA should be indicated to cover the roundtrip delay between Satellite and Gateway at least for position based TA estimation.  **Proposal 3**: Whether or not to support reporting of UE’s estimated TA should be further discussed.  **Proposal 4**: Pre-compensated TA value can be updated based on UE specific TA estimation and/or TA drift rate during long UL transmission.  **Proposal 5**: Frequency offset estimation should be supported by GNSS-capable UE for pre-compensation. |
| Interdigital (R1-2103273) | **Proposal 1**: non-essential issues should be down-prioritized in Rel-17 to expedite progress for Rel-17 IoT NTN.  **Proposal 2**: any issues related UE power consumption impact study should be down-prioritized in Rel-17.  **Proposal 3**: a UL gap longer than 40ms is considered for IoT NTN. |
| Sony (R1-2103319) | **Observation 1**: The maximum rate of change of flight time between UE and eNodeB is ± 50s / sec.  **Observation 2**: The cyclic prefix budget for time misalignment can be exceeded within 9.4ms.  **Observation 3**: The rate of change of subframe timing depends on the eNB location.  **Observation 4**: The IoT-NTN UE cannot determine the rate of change of subframe timing on the feeder link.  **Proposal 1**: The UE updates the timing of its PUSCH transmissions every ‘N’ ms, where ‘N’ is either 8 or 16ms.  **Proposal 2**: The eNB signals the rate of change of subframe timing on the feeder link, or timing drift rate, to the UE. The UE adds the timing drift rate on the feeder link to the rate of change of subframe timing on the service link to determine the timing adjustments that are applied during long UL transmissions.  **Proposal 3**: A timing advance command is associated with a reference point. The reference point indicates which node (UE, eNodeB or satellite) the timing advance command refers to.  **Proposal** 4: A timing advance command is associated with a reference time. The reference time indicates the time at which the timing advance is valid. The reference time of the timing advance command can be signaled to the UE either in MAC CE or PDCCH.  **Proposal 5**: The motion of the NTN aerial platform is signaled to the UE using position and velocity information and the drift rate of the timing on the feeder link.  **Proposal 6**: The position / velocity / drift rate (PVD) information is signaled using SIB signalling.  **Proposal 7**: RAN1 studies ways of mitigating PRACH congestion when IDLE mode UEs simultaneously transmit PRACH after receiving satellite PVD information. |
| Lenovo/Motorola (R1-2103528) | **Proposal 1**: A common timing offset (TO) and a TO drift rate for the propogation delay of feeder-link are broadcast in SIB.  **Proposal 2**: UE can calculate distance/delay for service link and update the distance/delay based on the satellite velocity.  **Proposal 3**：For TA maintenance, the UE needs to update N\_TA based on closed loop and N\_(TA,UE-specific)+N\_(TA,common) based on open loop mechanism.  **Observation 1**: For NPUSCH transmission with large number repetition, the TA adopted in the beginning is not suitable in the middle/end of the TB transmission.  **Proposal** 4: TA value drift during the repetitions should be considered in UL transmission in IoT on NTN. |