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***

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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

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| (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) |  |  |  |
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Table 7.2.4.5-1: Power consumption assumptions

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| ***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 %.

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| GNSS TTFF (hot start 2s), 2h report |
| Source | HuaweiMCL=154 dB, 105 bytes UL, 320 ms report, GNSS 100 mW | MediaTekMCL=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 % |

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| GNSS TTFF (warm start 5s), 12h report |
| Source | Huawei105 bytes UL, 320 ms report, GNSS 100 mW | MediaTek50 bytes UL, 238 ms report, GNSS 100 mW  | CATT50 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.

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| GNSS TTFF (hot start 1s), 2h report |
| Source | MediaTekMCL=154 dB, 50 bytes UL, 238 ms report, GNSS 37 mW  | EricssonMCL=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 % |

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| GNSS TTFF (warm start 5s), 24h report |
| Source | MediaTekMCL=154 dB, 50 bytes UL, 238 ms report, GNSS 37 mW  | EricssonMCL=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 $8$ hrs, once every $24$ 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** $34\%$ **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 $\~45\%$ **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** $\~10s$**), 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. 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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## 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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### 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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### 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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## 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 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).

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).

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. .

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.

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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## 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 | $$T\_{CP}$$ | $$T\_{SEQ}$$ | Duration of one repetition |
| 0 | 4 |  |  | 5.6ms |
| 1 | 4 |  |  | 6.4ms |
| 2 | 6 |  | 3$∙24576T\_{s}$ | 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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## 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.

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

|  |  |  |
| --- | --- | --- |
| 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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## 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 $45\%$ **to** $17\%$ (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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## 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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# Conclusions

TBA

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# Appendix A

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

## Huawei battery life analysis (R1-2102344)

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

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| --- |
| **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**

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| --- |
| **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 $C\_{DL}$) | Duration |
| GNSS reception | $$C\_{GNSS}=1.1×C\_{DL}$$ | $2000$ **ms** |
| Downlink Reception | $$C\_{DL}$$ | 1. PDCCH: $40$ **ms**
2. PDSCH (RAR): $8$ **ms**
3. PDSCH (Msg4):$8$ **ms**
4. PDSCH (Conn. Release): $8$ **ms**
 |
| Uplink Transmission | $$C\_{UL}=4.3×C\_{DL}$$ | 1. PRACH: $1.6$ **ms**
2. Msg3: $8$ **ms**
3. PUSCH (data): $8$ **ms per ~**$1000$ **bits**

(*simulated with 8000 bits per ON-duration*)1. HARQ-ACK: $8$ **ms**
 |
| Sleep | $$C\_{sleep}=\left(5.5×10^{-5}\right)×C\_{DL}$$ | 1. PSM: **8 hrs**
2. CDRX: $\~10s$
 |



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** $34\%$ **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** $\~10s$**), 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.**

## 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 ($N\_{TA,UE-specific}$), which can be calculated based on GNSS-acquired UE position and serving satellite ephemeris, and network indicated common TA ($N\_{TA,common}$) 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 ($N\_{TA,UE-specific}$), which can be calculated based on GNSS-acquired UE position and serving satellite ephemeris, and network indicated common TA ($N\_{TA,common}$) 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 + $FO\_{doppler}$.***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 $34\%$ 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 $\~10s$), 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.* 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 $45\%$ **to** $17\%$ (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.**
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| 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. |