**3GPP T****SG-RAN WG2 Meeting #116-bis-e R2-220xxxx**

**E-Meeting, Jan 17th – Jan 25th, 2022**

**Agenda item:**  **8.10.3.x**

**Source: Intel Corporation**

**Title: Report of email discussion [Post116-e][111][NTN] UE capabilities (Intel)**

**Document for: Discussion**

# Introduction

This is the report of the following email discussion:

* [Post116-e][111][NTN] UE capabilities (Intel)

Scope: discuss UE capabilities for NR NTN

Intended outcome: summary of the email discussion & initial running CR

Deadline: Long

Rapporteur suggests to split the discussion in two phases:

**Phase 1**: To collect companies’ views on NR NTN UE capabilities; The **deadline for this 1st phase** of email discussion is **Dec. 10, 0900 UTC.**

**Phase 2**: To finalize the draft running CRs; The **deadline for this 2nd phase** of email discussion is **Dec. 17, 0900 UTC.**

# Discussion

In RAN2#116e meeting, the discussion on UE capabilities was initiated based on [1] and [2], but due to limited online discussion time, no agreements have been made. In this long email discussion, companies are invited to further provide inputs to the following questions.

## UE capability differentiation and prerequisite

In [1], the following discussion point is suggested for online discussion, i.e., “whether to define separate UE capabilities for GEO case and LEO case”. According to the latest stage-2 running CR [3], the concepts of GEO and LEO have been changed to GSO and NGSO. Since the UE supporting GSO and the UE supporting NGSO may need different enhancements, it also leads to different requirements of UE capabilities. So on NR NTN UE capabilities, the first question would be whether to define separate UE capabilities for GSO case and NGSO case.

**Question 1: companies are invited to provide views on the following two options:**

**Option 1: define single NR NTN UE capability, i.e., when UE indicates it, it means UE supports both GSO case and NGSO case;**

**Option 2: define separate UE capabilities for GSO case and NGSO case.**

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| **Company** | **Which option is agreeable?** | **Comments** |
| OPPO | Option 1 as baseline | It may not be easy to draw a clear line and category which capabilities are specific to GSO case and which other capabilities are NGSO-specific. Having single set of UE capabilities for NTN can be taken as baseline for now. |
| Qualcomm | Option 2 with clarification (probably option 3) | It should be possible to indicate GSO and NGSO differentiation for some UE capabilities. For example, support of HARQ feedback disabling may be necessary for GSO but not for NGSO. However, we also think there may not be large difference between GSO to introduce separate UE capability containers for GSO and NGSO.  Simply within the same UE capability container, differentiation between GNS and NGSO would be needed for some capabilities. |
| Apple | Option 2 | We think that UEs that support NGSO will also be able to support GSO, even though GSO will require support of HARQ disabling and additional parameter values (e.g., for RLC and PDCP timers) due to larger UE-gNB RTT. NGSO support requires additional capabilities e.g., for mobility management. |
| Lenovo, Motorola Mobility | Option 1 as baseline | We prefer a single set of UE capabilities for NTN. The difference between GSO and NGSO can be further specified in the set. |
| Xiaomi | Option 1 | A single set of UE capabilities for NTN is baseline. If the capabilities are different for NGSO and GSO are identified, the capabilities can be specified per UE. |
| LG | Option 1 | We do not think separate capability is needed. If different altitude is the reason for different capability between GEO and LEO, then we also need different capabilities for each altitude of LEO satellite because the maximum altitude is twice higher than the minimum altitude (600km ~ 1200km). |
| Ericsson | Option 1 | We have not identified any capabilities that needs to be differentiated between GSO and NGSO. Even if such capabilities are identified later, it will be sufficient for each feature to have separate capabilities and then maybe some may be necessary for GSO and others for NGSO. |
| Huawei, HiSilicon | Option 1 for most capabilities, Option 2 should be discussed case by case | For most features, a per-UE capability is enough. If some capability is identified as GSO-specific or NGSO-specific (e.g. time-based CHO is necessary for NGSO, but not for GSO), it can be introduced as *“CapabilityName-GSO”* or *“CapabilityName-NGSO”* (Option 2). |
| NEC |  | There is some feature which may be essential to support NGSO but not for GSO, or visa verse. on the other hand, most features are required for both NGSO and GSO. We need a solution between option1 and option2 |
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In [2], the following discussion point has been touched during online discussion, i.e., “whether every UE supporting NR NTN in this release must be with GNSS capability, and whether such a GNSS capability needs to be signalled to the gNB”. And one thing to notice is that in R16 the following GNSS UE capability has been defined:

| ***gnss-Location-r16***  Indicates whether the UE is equipped with a GNSS or A-GNSS receiver that may be used to provide detailed location information along with SON or MDT related measurements in RRC\_CONNECTED, RRC\_IDLE and RRC\_INACTIVE. | UE | No | No | No |
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So the question for further discussion could be “whether to use *gnss-Location-r16* as the Prerequisite for R17 NR NTN UE capability” or “whether *gnss-Location-r16* is conditionally mandatory when NR NTN UE capability is indicated”.

**Question 2: companies are invited to provide views on the following two options:**

**Option 1: use *gnss-Location-r16* as the Prerequisite for R17 NR NTN UE capability;**

**Option 2: *gnss-Location-r16* is conditionally mandatory when NR NTN UE capability is indicated.**

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| **Company** | **Which option is agreeable?** | **Comments** |
| OPPO | Option 1 | The field description needs to be updated to cover NTN case. |
| Qualcomm | Option 2 | It should be conditionally mandatory, i.e., this field shall be included when UE indicates the support of NR NTN access. We agree the description of gnss-Location-r16 needs to be updated to cover NTN. |
| Apple | Option 1 | Agree that field description will need to be updated for NTN. |
| Lenovo, Motorola Mobility | Option 1 | We think this release is discussed under the assumption of GNSS capability, and updating the field description for NTN is needed. |
| Xiaomi | None | UE don’t need to report its GNSS capability to network since the network will assume all NR NTN UEs have the GNSS capability. And NR NTN UE can’t access to the NTN network if it hasn’t GNSS capability. |
| LG | Option 2 |  |
| Ericsson |  | If using the existing field, the field description needs to be updated.  Possibly, GNSS capability can be implicit as Xiaomi suggests, but then maybe some “NR NTN UE” needs to be defined as the ability to access an NTN may need to be indicated to the network in TN to enable configuration of HO to NTN.  Thus, we need to discuss if a “NR NTN UE” needs to be defined. |
| Huawei, HiSilicon | Option 2 | Same view with QC. GNSS capability is necessary for NTN UEs. |
| NEC | Option 2 | As indicated WI, location capability should be conditionally mandatory.  With option1, what if a UE indicate that it does not GNSS capability but have TA pre-compensation capability. |
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## User plane enhancements

In order to support NTN, a bunch of new features have been defined in Rel-17 NTN WI. And it’s necessary to differentiate essential from optional sub-features. The main idea is that adaptations of fundamental process are essential to support NTN feature, and optimizations in some respects could be optional, which means an NTN UE may choose not to implement this sub-feature.

For enhancements to user plane, Fig.1 is an example to distinguish sub-features that can be categorized as essential to enable Rel-17 NTN and optional ones.



**Fig. 1 Enhancements to user plane**

The UP enhancements categorized as essential includes the adaptations of RACH and HARQ, and the other timer extension to accommodate long RTT in MAC (extended sr-ProhibitTimer and configuredGrantTimer), RLC and PDCP layers.

TA reporting is used to optimize uplink scheduling for reducing transmission delay, it can be optional. And HARQ related optimization, such as disabling HARQ feedback for downlink transmission, new HARQ state for uplink transmission and the corresponding new LCP rule for dynamic grants, which are used to avoid HARQ stalling and reduce HARQ delay, can be optional as well.

**Essential sub-feature** means when UE supports NTN this component is supported by default, i.e., No Need of separate indication for this UE capability;

**Optional sub-feature** means when UE supports NTN, UE can further choose whether to support this component, i.e., for connected mode sub-feature it is optional with capability signalling, while for idle/inactive mode sub-feature it is optional without capability signalling. Meanwhile, it’s also possible for normal UEs to support some NTN enhancements, e.g., location based CHO, without supporting the whole NTN feature.

**Question 3: companies are invited to provide views on the differentiation of user plane enhancements:**

**Essential sub-features include:**

1. **the adaptations of RACH;**
2. **the adaptations of HARQ;**
3. **the timer extension to accommodate long RTT for other MAC timers (e.g., extended sr-ProhibitTimer and configuredGrantTimer);**
4. **the timer extension to accommodate long RTT in RLC and PDCP layers.**

**Optional sub-features include:**

1. **TA reporting (TA reporting during RACH using MAC CE, and Event-triggers for TA reporting in connected mode);**
2. **disabling HARQ feedback for downlink transmission;**
3. **new HARQ state for uplink transmission and the corresponding new LCP mapping rule for dynamic grants.**

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| **Company** | **Is this differentiation agreeable? (Y or N)** | **Comments** |
| OPPO |  | Adaptations of HARQ are associated with disabling HARQ feedback for DL and new HARQ state for UL. We think they should be grouped together |
| Qualcomm | No | We agree with working on the differentiation between essential vs optional features.  HARQ adaptation may not be essential as NTN can work without HARQ adaptation. It is already agreed that For HARQ process(es) not configured with DL HARQ feedback enabled/disabled, drx-HARQ-RTT-TimerDL behaves as per legacy. Similarly, for *configuredGrantTimer*, as configured grant may not be configured in NTN.  If NTN works without a given feature, e.g. due to lack of IOT, that feature should be considered non-essential. |
| Apple | Y | OK with moving HARQ adaptations to optional sub-feature. |
| Lenovo, Motorola Mobility |  | Agree with OPPO that HARQ adaptation is associated with disabling HARQ feedback for DL and new HARQ state for UL. |
| Xiaomi | N | DRX HARQ RTT timer extension should be essential, otherwise, DRX retransmission timer would expire before UE-gNB RTT for e.g. GEO case.  On the other hand, DL HARQ feedback enable/disable and UL HARQ state can be optional, given that it is used to optimize HARQ stalling and delay issue. Consequently, LCP restriction for UL HARQ state can be optional too. |
| LG | Y |  |
| Ericsson | No | We agree to make this division, but it is a bit unclear what each “sub-feature” includes.  What is meant by the adaptations of HARQ? For example, the running MAC CR does not contain any change in HARQ sections that is not related to the stuff listed under “Optional sub-features”. Is it the extension of DRX timers, then that is non-essential, as DRX power saving is optional for the NW to configure. Is it the 32 HARQ processes defined by RAN1? RAN1 already have a UE capability for 32 HARQ processes. |
| Huawei, HiSilicon | See comments | Maybe the rapporteur can further clarify the purpose of the differentiation. If the purpose is to group all essential capabilities into one single capability, and when the UE reports this capability, the UE can further report other non-essential capabilities, then it is ok for us. Anyway, the UE capabilities related to NTN should not be mandatory.  On “HARQ RTT timer adaptations”, does it refer to state A (timer is extended)? In other words, state A is the default state, and UE can report whether it supports state B. |
| NEC | Yes | We agree with the analysis in general. For DRX timer relevant to HARQ, it seems essential if DRX is configured and HARQ feedback is not disable? |
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## Control plane enhancements

For enhancements to control plane, as an example Fig. 2 is used to distinguish essential sub-features and optional sub-features.



**Fig. 2 Enhancements to control plane**

Regarding idle mode enhancements in control plane, TN prioritization over NTN should be essential to make a UE camping on TN cell, when possible, and get better service. Soft TAC update is used to support the case when a cell covers more than one TAC, and it’s a must-have as every UE may need to handle this case. Reporting coarse UE location is for CGI remapping in network, which is a basic requirement from network management point of view, so it should be essential too.

Cell reselection enhancements, such as stop-time based neighbour cell measurements and location based cell reselection criteria, can be considered as optional sub-features since legacy cell reselection process can still be used in NTN without obvious drawback.

Regarding connected mode enhancements in control plane, periodic location reporting has been supported in specification, but it’s only for MDT purpose. RAN2 needs to confirm with SA3 that it can also be used in NTN scenario as well.

But location reporting triggered by a location event is an optimization, and it can be optional. The CHO feature is optional in R16, so in R17 the further enhancements with new triggers should also be optional. The SMTC enhancements are for more accurate adjustments for neighbour cell measurements and can be considered as optional sub-features.

**Question 4: companies are invited to provide views on the differentiation of control plane enhancements:**

**Essential sub-features include:**

1. **TN prioritization over NTN;**
2. **soft TAC update;**
3. **reporting coarse UE location;**
4. **periodic location reporting.**

**Optional sub-features include:**

1. **cell stop-time based neighbour cell measurements;**
2. **location based cell reselection criteria;**
3. **location reporting triggered by a location event;**
4. **SMTC enhancements (event-triggered assistance information reporting, up to 4 SMTC, and UE based solution in idle/inactive);**
5. **CHO enhancements (time based and location based CHO).**

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| **Company** | **Is this differentiation agreeable? (Y or N)** | **Comments** |
| OPPO |  | For location-related sub-features marked by rapporteur as Essential, we prefer to defer the discussion after RAN2 formally treats SA3’s reply LS and decides to have those features.  For SMTC enhancements, we have different understanding on the essentiality. Without enhancements, UE may not be able to correctly detect and measure neighbour cells and this will eventually cause mobility issues. |
| Qualcomm | No | Please see our response in Q3. If NTN works without a given feature, e.g. due to lack of IOT, that feature should be considered non-essential.  For example, TN vs NTN priorities could be handled with existing mechanism. |
| Apple | Y | We are mostly fine with this division but have a couple of differences in opinion. (1) We think reporting coarse UE location and periodic location reporting should be optional (2) for SMTC need to further differentiate between 2 and 4 SMTC. |
| Lenovo, Motorola Mobility | N | We would like to postpone the location report sub-features and wait for SA3 reply as well as RAN2 final agreements. For the SMTC enhancements we think it is essential, at least for the assistance information reporting. |
| Xiaomi | N | We think soft TAC update are essential features. For UE location reporting, as we discussed in the previous meeting, the core network can acquire the UE location based on the LCS procedure, so the UE location reporting isn’t essential feature.  For TN prioritization over NTN, in RAN2#115e, it was agreed that RAN2 continue discussing the exact solution for TN prioritization over NTN for idle mode, so if the existing parameters are used to indicate the prioritization, such as, frequency priority, we think it is no need to introduce UE capability for TN prioritization over NTN. So we can determine it later. |
| LG | Y |  |
| Ericsson | No | Agree to make this type of differentiation.  We think the triggered location reporting is an essential sub-feature and periodic is not.  The SMTC enhancements is an essential feature for enabling measurements on neighbours as each neighbour may have its own timing.  The CHO is optional in R16, but for NTNs these enhancements to CHO are important to make the cell switches in quasi-earth fixed deployments work. |
| Huawei, HiSilicon | N | TN prioritization over NTN: Currently no prioritization method is adopted, the prioritization can be based on NW implementation (e.g. higher priority for TN frequencies), so no UE capability is needed.  Reporting coarse UE location: SA3 has replied with security concerns (S3-214360), so the related agreements need to be revisited, and the capability can be postponed.  Periodic location reporting: We think this capability should be made optional since it depends on user consent.  Time-based CHO and time-based reselection: These two capabilities should be considered essential. Location-based CHO/reselection requires UE to perform GNSS fixes and lead to much power consumption, whereas time-based CHO/reselection will not cost too much extra effort. If neither time-based nor location-based is supported by the UE, the overall performance will be degraded as the legacy RSRP-based mobility does not work well in NTN. |
| NEC | See comment | TN prioritization over NTN:  we cannot recall any special enhancement has been agreed on this, we only agree to relay on existing mechanism (e.g., absolutely frequency priority), so we are not sure we need to list this feature,  SMTC:  Last meeting, we discussed whether 2 SMTC should be mandatory supported by UE. this should be listed. Our opinion is mandatory  Location report in connected mode:  Both events triggered and periodic location report are functionally important, both are able to serve the same purposes. It should be up to network implementation which one is to configure. RAN2 can consider both should be mandatory for NTN UE, while still need to wait and take into account SA3 response for privacy aspect  CHO  It is reasonable that CHO is an optional feature in Rel16 for TN network, but for NTN, CHO is fundamental to reduce the mobility interruption considering long RTT.  We should consider to make CHO conditional mandatory to NTN, or at least, Location/timer/A4 based CHO can be conditional mandatory for UE support NTN and CHO. Otherwise, It would be difficult for network implementation.  Soft TAC:  Soft TAC particularly soft TAC update is essential for earth- moving cell scenario only in our understanding. |
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## Other issues

Regarding all the RAN2 determined UE capabilities above, there is no need to make FRX/XDD differentiation, and the granularities can all be per UE.

**Question 5: companies are invited to provide views on the following proposal:**

**Regarding all the optional RAN2 determined sub-features with capability signalling above, there is no need to make FRX/XDD differentiation, and the granularities can all be per UE.**

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| **Company** | **Is this proposal agreeable? (Y or N)** | **Comments** |
| OPPO | Yes | So far we don’t see any FRX/XDD difference, but we can always come back to this later if we identify some. |
| Qualcomm | May be | As it is likely that TN and NTN operate in separate bands, generally we prefer to have the UE capability per band for the reason to indicate feature sets for different RAT e.g., TN vs NTN.  Otherwise, we would need TN/NTN differentiation and also FRX differentiation. We think XDD differentiation is not needed. |
| Apple | Y |  |
| Lenovo, Motorola Mobility | Y |  |
| Xiaomi | Y |  |
| Ericsson | Yes | We agree no differentiation is needed, but TDD was not considered in NTNs for obvious reasons. Further, FDD has not been defined for FR2. |
| Huawei, HiSilicon | Y | For the capabilities discussed in above questions, we don’t see the necessity for FRX/XDD differentiation. |
| NEC | Y | At least RAN2 features are FRX and XDD agnostic as of now |
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**Question 6: companies are invited to provide other NR NTN UE capabilities that have not been covered in this offline discussion:**

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| **Company** | **Comments** |
| OPPO | On CP:  For the new NTN SIB, probably we need a separate UE capability to indicate that the UE supports the new SIB.  And capability related to multiple gaps for connected mode seems missing here.  On UP:  UE capability of increased HARQ process number. |
| Qualcomm | 1. We should discuss if we need to distinguish the UE capability within NSGO (i.e., LGE and MEO). 2. We think it should be discussed if we need to define additional UE capability (or IOT bit) for the existing TN features as they are not tested in NTN environment. RAN2 may need to ask other WGs to check. |
| LG | The capability for the extension of the number of HARQ process may be needed. |
| Ericsson | We note that RAN1 have agreed an LS to RAN2 with all UE capabilities in R1-2112903. They have indicated one capability for the number of HARQ processes, UE reporting information about the UE specific TA pre-compensation, and UEs ability to receive a UE specific K\_offset among other capabilities. |
| Huawei, HiSilicon | Same view with Ericsson, some capabilities have already been included in the RAN1 feature list (R1-2112902), so no need for duplicated discussion in RAN2:  Uplink Time pre-compensation (optional with signalling);  UE reporting of information about the UE specific TA pre-compensation (optional with signalling);  Increasing the number of HARQ processes (optional with signalling). |
| NEC | Should we further distinguish quasi-cell fixing and cell moving scenario in NGSO |
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# Conclusion

# References

[1] R2-2109636 Consideration on RAN2-determined NTN UE capabilities Intel Corporation

[2] R2-2109974 Discussion on UE capability for Rel-17 NR NTN vivo

[3] R2-2111613 Stage 2 running CR (Thales) THALES