3GPP TSG RAN WG1 Meeting #104e R1-2XXXX

**e-Meeting, January 25th – February 5th, 2021**

Agenda Item: 8.4.4

Source: Moderator (OPPO)

Title: Summary #1 of 8.4.4 Other Aspects of NR-NTN

Document for: Discussion and Decision

# Introduction

This document contains a summary of the contributions under AI 8.2.4 at RAN1#104e. This include the topics for RAN1 that should be specified if beneficial and needed as listed in Release-17 NR NTN WID:

* *Enhancement on the PRACH sequence and/or format and extension of the ra-ResponseWindow duration (in the case of UE with GNSS capability but without pre-compensation of timing and frequency offset capabilities) [RAN1/2].*
* *Feeder link switch [RAN2,RAN1]*
* *Beam management and Bandwidth Parts (BWP) operation for NTN with frequency reuse [RAN1/2]*
  + *Including signalling of polarization mode*

# Beam management discussions

In this section, we discuss beam management related issues and potential enhancements.

## Background

The following agreements were made in RAN1#102e

Agreement:

One-beam per cell and multiple-beam per cell are supported in existing NR specifications and are baseline for NR NTN.

* FFS: The need for potential enhancement for beam management
* FFS: The need for potential enhancement on association of SSBs, beams and BWPs

In this meeting, many companies have expressed their views on the follow-up questions based on the above agreement. The views indeed touched different aspects and they can be divided into following sub-topics. In section 2.2, the moderator summarizes companies’s views respect to the individual sub-topics.

* Cell vs. SSB beam, BWP#0 vs. BWP#x beam layout
* SSB transmission in BWP#0 and sync raster
* SSB beam, data beam and BWP association
* Beam switching
* Beam measurement and reporting

### Cell vs. SSB beam, and BWP#0 vs. BWP#x beam layout

During the rel-16 NR NTN SI, it was observed that the rel-15 NR beam management and BWP procedures can be re-used with the assumption that the beams are not co-located. Rel-15 NR UE uses initial BWP#0 for initial cell access including SSB, paging, and PRACH. There can be up to 4 BWPs configured in Rel-15 NR – i.e. BWP#0, BWP#1, BWP#2, and BWP#3.

There were two options for mapping of PCI and SSB in TR 38.821 [2].

* Option a: multiple SSB beams per PCI.
* Option b: one SSB beam per PCI.



***Figure 1: Mapping options for PCI/SSBs in NTN***

Further, in RAN1#103e meeting, we have discussed the following two beam layout options corresponding to two different relationship between BWP#0 and BWP#x. Option 1 implements a narrow beam in BWP#0, which has the same beam width as the data beam. While Option 2 has a hierarchical beam layout, which implements a cell-level large beam in BWP#0, a.k.a. umbrella beam.



*(a)* ***Option-1****: Same beam layout in BWP#0 and BWP#x (b)* ***Option-2****: hierarchical beam for BWP#0*



***Option-1****. A Narrow SSB beam*



***Option-2****: Wide SSB beam*

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| **Source** | **Related Proposals & Observations** |
| OPPO | *Proposal 3: In Rel. 17, a SSB beam is assumed to be a satellite beam.*  *Proposal 4: two options of SSB transmission are studied:*   * *Option 1: Rel. 15 concept, i.e. different SSB beams are transmitted at the same SS raster in the same initial BWP* * *Option 2: Following frequency reuse concept, i.e. different SSB beams are transmitted at different SS rasters in the different initial BWPs* * *Taking option 1 as a baseline.* |
| vivo | *Proposal 2: Multiple beams per cell should be prioritized.* |
| MTK | *Observation 1: Wide beam transmitting initial BWP#0 and multiple narrow beam spots transmitting data, where each narrow beam spot can be associated with dedicated BWP#1,2,3 for data transmission allows to re-use Rel-15 Beam management mechanisms.*  *Observation 2: Wide beam transmitting initial BWP#0 and multiple narrow beam spots transmitting data, allows scaling of L1 overhead and cell-specific overhead scaling by 1/(N+1) where N is the number of narrow spot beams within the wider beam.*  *Observation 3: EIRP splitting between wider beam and N narrow beam spots marginally reduce EIRP for data on narrow beams by 10\*log(N/[N+1]) dB.*  *Observation 4: Narrow beam transmitting initial BWP#0 and dedicated BWP#1,2,3 for data transmission allows to re-use Rel-15 Beam management mechanisms* |
| Lenovo | *Proposal 3: Study the restriction between beam and BWP.* |
| Ericsson | [Observation 1 Both multiple-beam and one-beam per PCI mapping schemes can be realized for NTN with current NR specifications without any enhancement.](#_Toc61720654) |
| InterDigital | *Proposal 2: consider different BWP allocation per beam as baseline when multiple beams per cell are used* |
| Huawei, HiSilicon | *Proposal 1: BWP configuration enhancement scheme should be studied for NTN, e.g.*   * *Extending the number of supported BWPs per cell* * *Introducing a scaling factor to adjust the cell-specific BWP common configuration* * *Adding initial BWP in dedicated BWPs.* |
| THALES | Observation 1 For loaded cells, Frequency Reuse schemes are needed to mitigate the inter-cell/inter-beam interference and improve the overall SINR  Observation 2 Spatial Frequency reuse schemes reduce significantly the inter-beam Co-channel interference but inherently limiting the per-beam bandwidth and the system capacity  Observation 5 Option (1) Single NR cell per satellite beam and single NR beam cell can be used as a baseline. With this option NR Beam management operation is not needed  Observation 6 The minimum size of NR beam is the satellite beam’s size  Observation 9 In the proposed solution, an a-priori BBWP planning can be used to allocate the BWP to each beam. Or a dynamic allocation can be performed by the gNB to configure beam-specific BWP based on the traffic distribution between the beams within the cell  Proposal 3 The new beam-specific BWP (BBWP) concept should be introduced on top of existing UE specific BWP  Proposal 4 The new beam-specific BWP (BBWP) should reuse Release-15/16 BWP operation procedures with the enhancements provided in this TDOC |
| Qualcomm | Observation 1: Different options for cell/beam/frequency planning call for flexible standard design.  Observation 2: Different beams of a satellite may have different carrier frequencies but the same corresponding UE transmit and receive spatial direction.  Proposal 1: Support satellite beam specific initial BWPs. |
| CATT | 1. For RRC-IDLE UE, one cell is only associated with one satellite beam, no enhancement needed. 2. For RRC-Connected UE, one small enhancement is considered:  * A cell comprises of multiple satellite beams with different coverage areas, wherein only one beam is linked to one initial BWP and other beams are linked to different active BWPs. |

### SSB and BWP association

In NR R15 specification, the NR beam association is realized by Transmission Configuration Index (TCI). The gNB indicate the serving beam via TCI on DCI or MAC CE. The TCI state includes fields for Cell index, BWP index, SSB index, CSI reference signal for a specific Control Resource Set (CORESET), which defines the PDCCH Search Space. For PDCCH, the MAC CE is used to activated one TCI state over a set of RRC configured TCI states for each CORESET. For PDSCH, DCI in the PDCCH can be used to indicate its TCI state, otherwise (i.e. the presence of TCI field in DCI is not configured), TCI state for PDSCH will follow PDCCH. In this meeting, we continue discussing whether RAN1 needs to define additional association between SSB and BWP. Companies’ views related to this issue are summarized below:

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| **Source** | **Related Proposals & Observations** |
| Ericsson | [Observation 2 Using BWP-BM association to enable a frequency reuse can already be supported by existing NR specification. It is a choice of network configuration and implementation.](#_Toc61720655)  [Observation 3 Mapping between BWP index and beam (SSB) index is already supported by current specification.](#_Toc61720656) |
| Xiaomi | *Proposal 1: The association between BWP ID and beam ID can be considered.* |
| Apple | *Proposal 1: The mapping between SSB index and BWP index, and SSB transmission in beam specific BWP0 are not supported.* |
| Qualcomm | Proposal 6: Consider efficient signalling of BWP configurations. |
| Fraunhofer HHI | Observation 1: Option-3 of “SSBs and BWPs association” reduces the latency in SSB measurements for NTN UE and preferable over option-1 and option-2 with respect to latency.  Proposal 1: RAN1 should consider option-3 of SSBs and BWPs association and leave option-3 for implementation in addition to working assumptions option-1 and option-2.  Observation 2: Overall specification impacts of option-4 of “SSBs, beam, and BWPs association” are substantially large. |
| THALES | Observation 9 In the proposed solution, an a-priori BBWP planning can be used to allocate the BWP to each beam. Or a dynamic allocation can be performed by the gNB to configure beam-specific BWP based on the traffic distribution between the beams within the cell  Proposal 3 The new beam-specific BWP (BBWP) concept should be introduced on top of existing UE specific BWP  Proposal 4 The new beam-specific BWP (BBWP) should reuse Release-15/16 BWP operation procedures with the enhancements provided in this TDOC |

### SSB transmission in BWP#0 and sync raster

In Rel-15 NR, initial beam selection is based on SSB detection before the PRACH procedure. All SSBs of the primary cell Pcell are transmitted in TDM manner over same frequency resource – i.e. SSB transmissions take place within a BWP and within the same frequency interval. The devices measures SSBs within the same frequency interval to determine the SSB index in time for the best beam and its corresponding CORESET for Common Search Space Set type 0 typically denoted by CORESET#0 (for SIB1). An SSB burst can contain up to 4 SSBs for frequencies below 3 GHz. This limits the number of beams to 4 assuming L or S band.

For NTN, analogue with the multi-beam layout in section 2.1.1, it is thus important to analyse whether it necessities any potential enhancement for SSB transmission in BWP#0 as well as the on the sync raster. In RAN1#103e meeting, the following two alternatives were discussed and in this meeting, companies provided their views in the respective Tdocs and summarized below.



Alt-1 vs. Alt-2 for SSB transmission in BWP#0.

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| **Source** | **Related Proposals & Observations** |
| OPPO | *Proposal 4: two options of SSB transmission are studied:*   * *Option 1: Rel. 15 concept, i.e. different SSB beams are transmitted at the same SS raster in the same initial BWP* * *Option 2: Following frequency reuse concept, i.e. different SSB beams are transmitted at different SS rasters in the different initial BWPs* * *Taking option 1 as a baseline.* |
| MTK | *Observation 5: SSB arrangements in different frequency intervals with beam-specific initial BWPs increase initial access time and need specification of new measurements with gaps due to frequent RF retuning and BWP switches.*  *Observation 6: If the 100 kHz sync raster grid for carrier frequency < 3 GHz is removed, the pre-compensation of the common Doppler shift over the access link by the gNB is not needed.*  *Proposal 1: The removal of the 100 kHz sync raster grid for carrier frequency < 3 GHz can be further studied.* |
| Sony | Proposal 1: SSBs of satellite beams in the same cell are transmitted in the same BWP, e.g., BWP#0. |
| Ericsson | [Observation 4 BWP specific transmission of CORESET#0, SIB1 and SSBs requires significant specification effort. The actual effect is equivalent to 1-beam per cell scenario.](#_Toc61720657) |
| THALES | Observation 10 The size of the common Initial-active BWP should be defined carefully to avoid any congestion and blocking within the cell |
| Qualcomm | Proposal 3: Support the following SSB arrangements   * Alt 1: SSBs of all satellite beams in a same cell are transmitted within a same frequency interval and do not overlap in time * Alt 2: SSBs of a cell are transmitted in different frequency interval, i.e., within their respective BWPs.   Proposal 4: Support signalling of the following configurations in SIB1   * initial BWPs of other satellite beams, * CORSET#0 of other satellite beams if different from that of the serving beam. |
| CATT | 1. SSB configuration in one BWP follows NR Rel-15 framework, no enhancement needed. |

### Beam switching

Many companies in their respective documents talked about the beam switching enhancement. In NR R15 specification, the beam switching was realized by TCI state indication. While for NTN, some companies proposed different ways to realize beam switching. Views are captured in the following table.

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| **Source** | **Related Proposals & Observations** |
| ZTE | *Proposal 6: Enhancement on beam management for UE-group based beam switching, can be considered to improve the performance.*  *Proposal 7: To reduce signaling cost and latency, UE dominant or UE assistant beam switch can be considered.*  *Proposal 8: Both BWP switching and TCI indication should be supported parallel to achieve the beam switching.* |
| CAICT | Proposal1 : Enhance BWP switching used for NTN beam switching to reduce beam switching latency. |
| vivo | *Observation 1:* *Beam switching is preferred to LEO scenarios with earth-moving beams.*  *Proposal 3: Support the association between BWP switching and beam switching.*  *Proposal 4: Support to reuse the specified TCI mechanisms.* |
| Sony | Observation 1: in Earth-fixed beam scenario, beam selection in UE side is needed.  Observation 2: in Earth-moving beam scenario, beam selection in both gNB side and UE side are needed.  Proposal 2: The beam used in UE side should be indicated by gNB via downlink information such as SRI in NTN.  Proposal 3: Reuse the beam indication and BWP indication method in Rel.15/16. Furthermore, the BWP indication and beam indication should be coordinated. |
| Ericsson | Proposal 1 RAN1 to discuss the scope of beam management, i.e., whether NR beam management framework (TCI state and spatial relations) should be restricted within the same satellite or support the switching of the service links associated with different satellites.  Proposal 2 A first satellite providing coverage before a service link switch should assist UEs in RRC connected with signaling of the ephemeris of the second satellite providing coverage after the switch.  Proposal 3 The NR network should be able to indicate the timing of the service link switch to UEs in RRC idle and RRC inactive modes.  Proposal 4 RAN1 to conclude that there is no need for additional enhancements for using BWPs to enable a frequency reuse. |
| Xiaomi | *Proposal 2: DL BWP switching and UL BWP switching simultaneously should be supported.*  *Proposal 3: Timer based BWP switching can be supported.* |
| Huawei, HiSilicon | *Proposal 2: In case of earth-fixed cells, whether there is a beam switch issue should be further clarified.*  *Proposal 3: In case of earth-moving cells, a UE in RRC connected mode can perform BWP switching based on a pre-configured mapping relationship between SSB index and BWP index.* |
| THALES | Observation 7 Beam management can be beneficial in case of multi-beam moving cell  Observation 8 Deploying multi-beam cell and using beam management will not be applicable to all NTN deployment scenarios  Proposal 5 Bandwidth part indicator field on DCI should be unchanged  Proposal 6 MAC CE transmission configuration indication (MAC CE TCI) can be used to indicate and update serving beam and implicitly the BBWP |
| Panasonic | Observation 1: For LEO, there is a potential issue of signaling overhead and UE power consumption caused by frequent beam switching by Rel-15/16 beam management.  Proposal 1: Schemes to reduce the signaling overhead and UE power consumption for beam management in moving cell scenarios can be considered, e.g. a list of multiple beams with associated timings for switching is indicated to the UE by RRC. |
| Apple | *Proposal 3: Consider associating beam switching with BWP switching.* |
| Qualcomm | Proposal 5: Consider BWP switching schemes to support efficient satellite beam switch. |
| Fraunhofer HHI | Proposal 3: RAN1 to strive for a unified solution to indicate beam switching in NTN.  Observation 4: In NTN, beam switching should trigger BWP switching, however, not every BWP switching should trigger beam switching.  Observation 5: Beam-specific BWPs consideration for NTN facilitates the design of unified solution for beam switching indication in NTN.  Proposal 5: RAN1 to clarify the scope of beam management enhancement. |
| CATT | 1. Support BWP based beam switching enhancement in NTN to reduce beam switching latency. 2. Enable BWP switching of UL and DL simultaneously and support UE confirmation after BWP switching successfully. 3. Support DCI to indicate beam switching with BWP index indication. |

### Beam measurement and reporting

In NR R15 beam management, the beam measurement is performed in the active BWP. For NTN, some issues are identified by companies and potential enhancements are investigated and summarized in the following table.

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| **Source** | **Related Proposals & Observations** |
| ZTE | *Proposal 5: To reduce power consumption and signaling cost, measurement can be disabled or be carried out with adaptive measurement period.* |
| vivo | *Proposal 1: Support to reuse Rel-15 beam management as baseline.* |
| Lenovo | *Observation 1: For NTN, current NR based measurement-based beam management will result in large signaling overhead and long latency for periodic exchange of CSI-RS transmissions and corresponding reporting.*  *Proposal 1: Study a common BWP or separate different BWPs for beam management.*  *Proposal 2: Consider impact of BWP switching delay for NZP CSI-RS for beam management configured at in corresponding BWPs.*  *Proposal 4: Study further methods to perform beam measurements in order to reduce the signaling overhead and avoid long latency.* |
| Sony | Observation 3: Beam measurement is necessary and the existing beam measurement method in Rel.15/16 can be reused in NTN. |
| InterDigital | *Proposal 3: study a mechanism to reduce the time gap to measure neighboring beams when frequency reuse is used for multiple beams in a cell* |
| Apple | *Proposal 2: Consider performing beam measurement either in initial BWP or in different BWPs with BWP switching.* |
| Qualcomm | Proposal 7: Consider enhancements on beam measurement and reporting to support efficient switching between satellite beams using different frequency. |

## Company Views (1st round discussions)

### Cell vs. SSB beam, and BWP#0 vs. BWP#x beam layout

Moderator summary:

Option 1 and option 2 satellite beam layout was discussed in different companies’ contributions.

MTK states that with hierarchical beam layout (option 2), the signalling overhead can be reduced while it will result in EIRP splitting. Advantage of option 1 beam layout is to allow reusing R15 beam management mechanism.

Ericsson states that multi-beam or one-beam per PCI mapping is gNB implementation and no specification enhancement is needed.

Vivo, InterDigital, Huawei, THALES state that multi-beam layout should consider frequency reusing. BWP vs. beam mapping should be supported.

Huawei, THALES, Lenovo, Qualcomm propose to define beam-specific BWP or beam specific initial BWP.

Moderator encourages companies to discuss the following items:

1. Cell vs. SSB beam
   1. Question: can multi SSB beams per PCI (option a) or one SSB beam per PCI (option b) be left for network implementation and transparent to specification?



1. Beam layout between BWP#0 and BWP#x:
   1. Option 1: BWP#0 has a same beam width as BWP#x beam.
   2. Option 2: BWP#0 has an umbrella beam and BWP#x have spot beams under the umbrella beam.
   3. Discussion: can these two beam layout options be left for network implementation and transparent to specification?



***Option-1****: Same beam layout in BWP#0 and BWP#x* ***Option-2****: hierarchical beam for BWP#0*

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| **Company** | **Comments and Views** |
| Panasonic | For item 1), we think both options a and b can be realized by current NR spec without further enhancement.  For Item 2), we think both options 1 and 2 can be realized by current NR spec without further enhancement. |
| vivo | **On Cell vs. SSB beam**  One beam per cell is a subset of multi-beam per cell, it can be naturally supported if we support the later one. Both of them can be left to NW implementation and transparent to UE.  **On Beam layout between BWP#0 and BWP#x**  Option-1 with less specification effort should be prioritized. The reasons are as below:  Firstly, Option-1 offers better compatibility with multi beams per cell and one beam per cell. However, considering one beam per cell, the meaning and purpose of BWP#0 in Option-2 are unclear and require further study.  Secondly, some parameters included in the umbrella beam need further discussion, for example, the polarization of the umbrella beam if there are polarization with frequency reuse.  Besides, there is no need for Option-1 to perform BWP switching periodically from BWP#x to BWP#0 to obtain cell-level system information.  In our view, these two beam layout options cannot be left for network implementation and transparent to specification. |
| ZTE | * For item-1: it has confirmed that both Options will be supported and all of them can be up to gNB implementation; * For item-2: from gNB perspective, all these beam layout (option-1 and 2) can be achieved by implementation. And Option-1 can provide better coverage for the common channel since there are mismatch on the antenna gain between BWP-0 and BWP-1 in option-2. |
| LG | Item 1: both options can be supported by current specification.  Item 2: both options can be supported by current specification. |
| Fraunhofer IIS, Fraunhofer HHI | For the 1st item: Both option-a and option-b are supported with the current spec and can be left to gNB implementation.  For the 2nd item: option 1 and option 2 can be supported with current spec. However, here these beam layouts cannot be transparent to specifications. |
| Ericsson | On 1), unclear what is the meaning of “transparent to specification” in the question. Existing specification can be used to support both options. The discussion point is whether additional enhancement is needed.  On 2), similar comment as in 1). |
| Thales | 1. both options can be implemented based on current NR specs without further enhancement. 2. both options can be implemented based on current NR specs without further enhancement. To be left to network implementation. |
| OPPO | For Q1: option a and option b can be supported by implementation  For Q2: option 1 and option 2 can be supported by implementation. |
| Moderator | Quick summary  For 1), It seems up to now companies agree that both option-a and option-b are supported by the current spec, and the selection can be handled by network implementation. Thus, no further enhancement in the spec is needed.  For 2), vivo thinks that to support option1 and option 2, the current spec is not sufficient, further enhancement is needed, e.g. the polarization of the umbrella beam if there are polarization with frequency reuse. |
| MediaTek | 1. Cell vs. SSB beam with options a and b can be support in Rl-15 specifications 2. Beam layout between BWP#0 and BWP#x with options 1 and 2 can be supported in Rel-15 specification |
| Huawei | 1. Both options are supported by current specification. 2. Both options are possible. Comparing option 1 and option 2, option 1 provide a better coverage. It is still unclear whether any specification impact is required. |
| Spreadtrum | For item 1), both options can be realized by current NR spec without further enhancement and transparent to UE.  For item 2), Option 1 is preferred given that it can provide better coverage for the common channel and bring less specification effort |
| Apple | On 1). Both options are supported by the current spec. It is due to network implementation.  On 2). Both options are supported by the current spec. It is due to network implementation. |
| Qualcomm | On 1), spec supports both. However, the question should be what is required in implementation to support option a) and if existing transparent satellites can be reconfigured to support it. Satellite with fixed analog antennas such as horn antennas cannot support option a. Satellite with steerable analog antennas can support option a) but additional enhancements in spec are needed.  On 2) , Current spec allows it and no implementation issue. |
| CATT | For 1) and 2), we think the current specification can support either option, but with the restriction that all beams sharing same PCI should have same frequency band. If different beam owns different frequency band, specification impact should be considered, especially for RRC-IDLE UE. |
| Sony | For (1) a), we think both option a and option b can be left for network implementation and supported by current specification;  For (2) c), we think both option 1 and option 2 can be left for network implementation and supported by current specification. |
| Xiaomi | 1. Both are supported 2. For option 2, possible enhancement may be needed. |
| Samsung | 1. Both options can be supported by current specifications. 2. Both options can be supported by current specifications. |

### SSB and BWP association

Moderator summary:

Companies provided your views and suggestions in their contributions on association between SSB, beam and BWP.

Xiaomi proposes to have association between BWP ID and beam ID.

Ericsson thinks the association between SSB index and BWP index is already supported in NR specification.

Apple proposes NOT to support explicit SSB index and BWP index mapping.

HHI and Qualcomm think it is useful to have association between SSBs and BWPs. Qualcomm further proposes to define an efficient signalling of BWP configuration.

Moderator encourages companies to discuss the following items:

1. Is the association between SSB and BWP already supported by the NR specification?
2. Do we need additional association to map SSB index and BWP index?

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| **Company** | **Comments and Views** |
| Panasonic | The intention of such “mapping” needs to be clarified first. We are not supportive that switching BWP always triggers the switching of beam and vice versa, if the mentioned mapping between SSB index and BWP index is introduced.  It seems the motivation of linking SSB index and BWP index is to facilitate frequency reuse factor larger than 1 to reduce the interference of neighboring satellite beams. Although we acknowledge that interference coordination among neighboring satellite beams are necessary in view of the fact that the coverage of neighboring beams can be largely overlapping, we don’t favor the semi-static frequency reuse planning such as increasing the reuse factor more than 1. Instead, interference coordination should be handled in more dynamical way and the Rel-15/16 BWP operation has already supported it. Note that BWP in Rel-15/16 is defined from individual UE perspective, and therefore when it is used for interference coordination in NTN, BWP can be configured and activated/de-activated for each UE individually based on the actual interference the UE is experiencing. If inter-beam interference is not so server from a given UE perspective, there is no need to switch BWP when the UE is switched to the neighboring beam. On the other hand, if BWP needs to be switched when beam is switched, Rel-15/16 BWP switching indication is also workable. The above flexibility would be lost if BWP is mandated to switched together with beam switching when beam-specific BWP is introduced. |
| vivo | There is no association between SSB and BWP in Rel-15 and Rel-16. BWP configuration is configured per CC and per UE, while SSBs are cell-level signals.  There is no need to map SSB index and BWP index. Different SSBs are associated with different beams, and if the association between BWP switching and beam switching is supported, the association between SSBs and BWPs would be determined naturally. |
| ZTE | The intention of “association” should be clarified. In existing NR, for single cell, all SSBs are carried in same initial BWP in TDM manner for accessing. No need to introduce the additional explicit mapping to support the implementation of beam with consideration on the frequency reuse via BWP. |
| LG | We think there is no association btw SSB and BWP in current specification. Also, no need to introduce additional association to map SSB index and BWP index. |
| Fraunhofer IIS,  Fraunhofer HHI | Fraunhofer is not supportive of introducing an association between SSBs and BWPs in general and do not see the need in doing that. In our contribution, we mentioned that IF option-3 of mapping between SSBs and BWPs is supported, according to the previous RAN1 FL recommendations, then, it is beneficial to have an association between SSBs and BWPs for option-3. |
| Ericsson | It should be first discussed what is the purpose of association. Then it can be discussed what is available and what is missing if any.  Take downlink for example. According to RRC signaling design, BWP-Downlink IE is a high-level IE with an ID field and additional cell specific and UE specific configurations. Within the cell specific and UE specific configurations, beams including their indices are configured. This already creates a linking between BWP index and beam index. |
| OPPO | NR specification uses QCL indication to make the linkage between SSB and BWP implicitly. However, the linkage might not be one-to-one mapping.  New association between SSB and BWP may be introduced so that the linkage relationship can be made more efficient. |
| Moderator | Quick summary  Many companies are not supportive on the SSB index and BWP index mapping and questioning about the motivation of such mapping.  The FL opinion on the motivation, based on the collected contributions, is that the mapping can ease the beam switching for FRF>1 case, e.g. BWP1 associated with SSB 1, BWP2 associated with SSB 2, thus triggering BWP1 switching to BWP2 can lead to a beam switching from SSB 1 to SSB 2.  The proposing companies [Xiaomi, Qualcomm, Fraunhofer HHI?] are invited to further provide their elaborations on this issue. |
| MediaTek | To our understanding, there is no explicit association between BWP and SSB index. Time-multiplexed SSB transmissions are in the initial BWP#0 in the same frequency interval. UE first access cell in initial BWP#0, determines the SSB index in time by measuring the SSB mapped to the best beam, and gets configuration of BWP via RRC signalling and activation via DCI.  It seems not essential to have explicit mapping between SSB and beam index. The current specifications could be re-used. |
| Huawei | Our understanding is that there is no explicit association between SSB and BWP in current specification. The main motivation to support such mapping is to enable beam switching and BWP switching at the same time. This mapping is beneficial for FRF>1, which a typical deployment in NTN. |
| Spreadtrum | There is no explicit association between SSB and BWP in current specification. We first need to discuss the issue of what is the purpose of introducing additional association to map SSB index and BWP index. |
| Apple | The association between SSB and BWP is not explicitly specified in NR terrestrial network. We also do not see the necessity of supporting it for NTN. |
| Qualcomm | Moderator’s quick summary is correct. To further clarify, SSB beam switching typically leads to a BWP switch when FRF>1. Without the association/mapping between SSB and BWP, BWP reconfigurations are needed whenever there is a satellite beam switch. |
| CATT | In NR specification, no explicit association between SSB and BWP. If introducing this association, it would have big impact to UE access procedure, but we don’t see the reasonable motivation for have this enhancement. |
| Sony | For (1), there is no association between SSB and BWP. But if the intention of SSB here is beam, there is explicit/implicit association between beam and BWP in current spec.  For (2), no additional association is needed. |
| Xiaomi | Our understanding is that currently when BWP is switched, there is an implicit indication of beam switch. Association between SSB and BWP can save the signalling overhead in case frequency reuse factor larger than 1 is applied for interference avoidance purpose. |
| Samsung | For both questions, our view is “no”. No need to enhance in this WI. |

### SSB transmission in BWP#0 and sync raster

Moderator summary:

Regarding SSB transmission in BWP#0 (initial BWP), companies’ views are split. There are mainly two directions to pursuit.

Alt-1: SSBs of a same cell are transmitted in a same frequency interval or in one BWP#0.

Alt-2: SSBs of a same cell are transmitted in different frequency intervals or introduce multiple BWP#0.

MTK proposes to enhance the sync raster by removing the 100 kHz grid for carrier frequency <3 GHz. The identified issue is that the due to large Doppler shift, e.g. +/- 75 kHz at carrier frequency < 3 GHz, 100 kHz raster grid will cause ambiguity for the UE.

Qualcomm proposes sync raster design to reduce initial access time by increasing the step size of the raster.

Moderator encourages companies to discuss the following items:

1. What are companies’ views on alt-1 vs. alt-2 and please provide pros and cons?



1. What are companies’ views on the sync raster issue brought up by MTK and Qualcomm?

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| **Company** | **Comments and Views** |
| Panasonic | Alt-1 is the current NR design and should be followed unless serious issues are identified.  Alt-2 has significant spec impact and seems not worth it. If multiple BWP#0 in different frequency intervals are intended, it can be alternatively realized by mapping to different PCIs. |
| **ZTE** | Alt-1 is same existing RN design, in which, all SSBs for one cell during the initial access stage is in same BWP. No additional spec impacts are identified to support it for NTN.  Alt-2 introduce additional efforts to define the multiple initial BWPs for single cell. |
| LG | Alt 1 is the same as current NR design, but Alt 2 has a huge impact on specification. |
| Ericsson | On 1), Alt-1 aligns with existing NR design and is sufficient. Alt-2 is a significant deviation from the fundamental access design in Rel-15 NR. It requires considerable amount of specification effort and the actual effect of this option is almost equivalent to 1-beam per cell setup, that is, each beam become almost like a cell.  On 2), we are open to discuss the sync raster issue further. Perhaps the proponents can provide evaluation results to demonstrate if it is an issue or not. |
| Thales | 1. Current NR design (i.e Alt-1) should be considered as baseline for NTN. Supporting Alt-2 will introduce a significant impact on the specifications and the benefits are unclear. 2. The issue mentioned by MTK may occur for specific NTN deployment scenarios where common Doppler precompensation on DL is not implemented. |
| OPPO | Alt-1 is inline with NR concept. The advantage is that less specification impact is expected. However, the drawback is that for example umbrella beam of BWP#0, significant amount of idle UEs might need to be requiring to access the network, resulting in a jamming situation. Moreover, for SSB based measurement, the UE may need to switch between BWP#0 and active DL BWP.  Alt-2 can resolve the jamming issue of Alt-1 and may not require UE to switch the BWP to perform SSB measurement. However Alt-2 may require quite a lot spec change. |
| Moderator | Quick summary  Majority companies think Alt-1 should be the baseline and Alt-2 requires large spec change.  Sync raster issue was not acknowledged by majority companies. MTK and Qualcomm are invited to bring simulation results to confirm the issue. |
| MediaTek | The common Doppler pre-compensation by Gnb gives a Doppler shift discontinuity at each bean switch which increases complexity of tracking algorithms and would need additional signalling. This could be a RAN4 discussion. Another issue is the delay drift impact on demodulation. With common Doppler pre-compensation over the access link, the impact of the delay drift over the access link cannot be removed during DL synchronization to the DL reference frequency. There is also the impact of the Doppler drift on the feeder link if not known. This could result in significant impact on PDSCH demodulation. We agree that simulation results to confirm the issue will be helpful. |
| Huawei | For Q1, Alt.1 is supported by current specification where all SSBs are carried in initial BWP. Alt.2 would require quite significant specification change and actually this option was also discussed at early phase of NR Rel-15. Our understanding is that the entire initial access procedure and measurement schemes will be changed. It is probably not the intention of NR NTN.  For Q2, we are not sure whether there is a need to removing the 100 kHz sync raster grid. Assuming frequency pre-compensation applied by the Gnb side, the residual frequency offset will not exceed 100 kHz, e. g. 600km LEO, Ka band, 50km beam diameter, the residual Doppler at cell edge is 16.2KHz. |
| Spreadtrum | Alt.1 is supported by current specification. Alt-2 has significant spec impact and its benefits are not clear. |
| Apple | We support Alt-1, which is aligned with the current NR design. The support of Alt-2 involves large specification changes, whose motivation is not justified. |
| Qualcomm | Alt.1 is supported by NE spec but will not be supported by satellites with fixed satellite antennas. For steerable antennas, additional enhancements may be needed for alt1. Alt 2 can be easily supported by all antenna types. |
| CATT | Alt1 is the baseline, and we don’t see the need to support Alt2. |
| Sony | For (1), we support Alt.1 as it aligns with current spec. Alt.2 has more significant specification impact. However, if the gain of such a method can be identified, we are also open to further discussed it. |
| Samsung | As other companies above explained, the current specifications are aligned with Alt. 1. We can just reuse Alt 1. |

### Beam switching

Moderator summary:

Companies provided your views and suggestions in their contributions on beam switching issues.

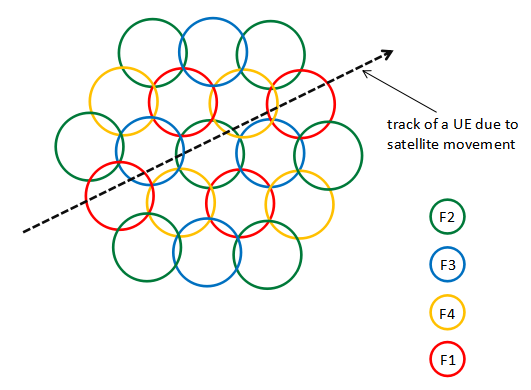
Beam switching realized by BWP switching has been discussed in many companies’ contributions: ZTE, CAICT, vivo, Sony, Xiaomi, Huawei, THALES, Apple, QC, HHI.

In addition, following beam switching enhancement is also discussed by companies

UE dominant beam switching: discussed by ZTE, Panasonic, Xiaomi

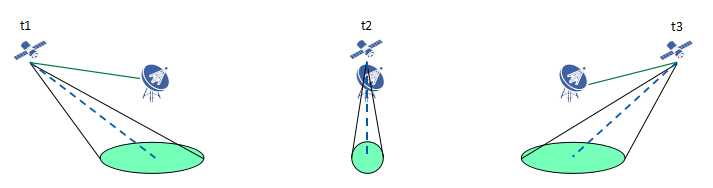
In case of earth-moving beams, the beam switching happens gradually with the movement of satellite. ZTE propose GNSS-capable UE can determine when to switch beams in two ways:

1. Option-1 Timer based: Network pre-configure UEs with beam switching timer based on UE position and beam layout information with satellite ephemeris, which conduct beam switching autonomously based on timer.
2. Option-2 Measurements based: Based on RSRP measurements and beam layout information with satellite ephemeris broadcast in SIB, UE autonomously do beam switching within the limited set accordingly.



gNB dominated beam switching: discussed by ZTE, Panasonic

In case of earth-fixed beam, the footprint of a satellite using steerable beam varies with elevation change, with dweling time in range 1 to 10 minutes. This makes periodical CSI-RS report ineffective. With GNSS assumption at UE side and broadcast of beam configuration in satellite ephemeris, UEs can calculate dwelling time. UEs close to beam edge can switch beam based on UE group-specific signaling assuming gNB has knowledge of UE positions.



In addition, Ericsson proposes to discuss whether the beam management can be used for service link switching between different satellites. Further a source satellite should provide ephemeris of the target satellite that the UE will switch to. The network should be able to indicate the timing of the service link switch to UEs in RRC idle and RRC inactive modes.

Moderator encourages companies to discuss the following items:

1. In addition to NR R15 beam switching mechanism (via TCI), do we need additional enhanced beam switching mechanism, e.g. via BWP switching?
2. Please provide companies’ views on gNB dominant beam switching and UE dominant beam switching. For UE dominant beam switching, please provide your views on timer based and measurement based alternatives.

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| **Company** | **Comments and Views** |
| Panasonic | 1. We are not supportive that switching BWP always triggers the switching of beam and vice versa. Such semi-static frequency reuse planning is not necessary. Instead, interference coordination should be handled in more dynamical way and the Rel-15/16 BWP operation has already supported it. Note that BWP as in Rel-15/16 can be configured and activated/de-activated for each UE individually based on the actual interference the UE is experiencing. 2. gNB dominated beam management is already the case in Rel-15/16. Probably the intention here is to reduce the unnecessary measurements and perform UE-group based beam switching. Actually, the measurements can be disabled via configurations, and furthermore, UE-group based beam switching seems not necessary because for LEO earth-fixed beam deployment, one-beam-one-cell mapping is more suitable without concerns of L3 handover overhead and RAN2 has already discussed UE-group based handover.   In case of earth-moving beam, we can first agree that **there is a potential issue of signaling overhead and UE power consumption caused by frequent beam switching by Rel-15/16 beam management.** Then it can be further discussed the timer based beam switching and location-based beam switching. |
| vivo | Support to study additional enhanced beam switching mechanism via BWP switching. The specified mechanism of BWP switching in Rel-15 and Rel-16 can be reused to reduce the signalling overhead. In NTN, frequency reuse is usually used to mitigate inter-beam interference. Hence, there is almost inevitable that beam switching would lead to switch another BWP.  gNB dominant beam switching is preferred, since network could directly provide beam-specific or cell-specific parameters for beam switching based on ephemeris information of satellites or other assistant information.  For UE dominant beam switching, there is no benefit on latency and needs to request these parameters related to switching. Though timer based beam switching might be a straightforward way, it will suffer performance degradation due to the elliptical satellite orbits and the irregularity of the earth's surface, even accumulated error. |
| ZTE | As we already identified in the study phase, the semi-persistent FDM allocation for each beam is one important way to avoid the inter-beam interference for NTN, corresponding the case as frequency reuse factor = 3 and 4. It's beneficial to support it from specification design perspective. Then, beam switching (from gNB perspective) can be naturelly achieved by BWP switching (e.g., even without additional refinement of the beam at Rx) .  It should be noticed that in NTN case, the foot print on the earth for each beam will be much larger, the corresponding refinement for switching from single UE perspective may not be 1st priority.  For the UE dominant switching, such solution can be considered as supplementary approach to reduce the measurement/report overhead. And as the tradeoff, UE triggered report can also be one way to optimize existing mechanism. |
| LG | 1) As commented by Panasonic, semi-static frequency reuse can already be supported by existing NR specification.  2) gNB dominant beam switching is preferred. |
| Fraunhofer IIS,  Fraunhofer HHI | In NTN, beam switching should trigger BWP switching, however, not every BWP switching should trigger beam switching. If beam specific BWP is introduced for NTN, any indication of beam switching via TCI or MAC CE can trigger the beam-specific BWP switch, while current NR BWP switching indications such as 1- RRC reconfiguration based BWP switch, 2- DCI-based BWP switch, and 3- Timer-based BWP switch can be used for non beam-specific BWP switch. |
| Ericsson | We should first identify what the problem (if any) is before discussing enhancements. Further, this BM discussion is coupled with the discussion on association of SSBs, beams and BWPs. |
| Thales | To enable Flexible Frequency Reuse, the concept of beam-specific BWP (BBWP) could be introduced. The objective is to replace the component carrier (CC) which is not as flexible as a BWP is. The same component carrier is used on all cells but each beam will be assigned a beam-specific BWP. The inter-beam interference mitigation will be based on BBWP following a frequency reuse scheme.  Bandwidth parts (BWP) are used to optimize UE operations in frequency domain, whereas the BBWP will be used to support flexible frequency reuse. The beam-specific BWP (BBWP) similar to UE’s dedicated BWPs should be configured independently (from UE’s dedicated BWPs) by network via dedicated RRC signalling.  The UE should be configured with as many BBWP as the number of beams within the cell. |
| OPPO | 1. Enhanced beam switching via BWP switching can be studied, if the BWP index and beam index association is defined. 2. gNB dominant beam switching is already supported in NR. For UE dominant beam switching seems to require large spec impact thus may be de-prioritized. |
| Moderator | Quick summary  Opinions are diverged. Some companies think that in NTN multi-beams are located in different frequency interval to reduce the inter-beam interference. These different frequency interval may be different BWP. Thus, the switching from one beam to the other beam may lead to a BWP switching. Similarly, triggering BWP switching may lead to a beam switching too as long as the relation between the BWP and the beam is clear. However, some companies think this is already supported by the current spec, thus the needs for additional enhancements is not clear.  Thales, Fraunhofer IIS, Fraunhofer HHI propose to define a beam-specific BWP in addition to NR BWP. The proposing companies are invited to further provide elaboration on the issues with the current NR BWP concept w.r.t. the beam management in NTN. Why the NR BWP cannot support flexible frequency reuse. |
| MediaTek | The potential problems could be further discussed before enhancements are discussed. It would be helpful to prioritize discussions on associations SSB, beams and BWP. |
| Huawei | We are in general open to enhancement for beam switching but it seems that the concept gNB dominated and UE dominated beam switching is still not quite clear. |
| Spreadtrum | We shared the similar views with MTK. |
| Apple | We support to study the association between beam switching and BWP switching. Frequency reuse can be used in NTN to mitigate inter-beam interference. With frequency reuse, the switching of beam is always associated with BWP switching. The association between these two facilitates the beam switching/BWP switching.  Like in NR terrestrial network, we prefer gNB dominant beam switching. The UE dominant beam switching seems to involve large spec. impact, which is considered as optimization to gNB dominant beam switching. Hence, we prefer to deprioritize the UE dominant beam switching. |
| Qualcomm | QCL type-D in TCI in NTN has different meaning than in TN from UE’s perspective. All satellite beams have the same QCL Type-D. A satellite beam switch does not mean spatial direction change from UE’s point of view but often means BWP switching when FRF>1. The question is then how to support efficient BWP switch (due to satellite beam switch). |
| CATT | For NTN case, FDM based beam multiplexing is popular. In order to support quick beam switching with short latency and less signalling, BWP switching shows clear benefit. So we support the association between the beam switching and BWP switching. When using gNB dominated beam switching, gNB can have full control for the beam switching and ensure reliable performance.  Current NR BWP switching has the following drawbacks:   * *BWP swtiching in UL and DL is separately configured, which is unsuitable for FDD NTN scenario.* * *If BWP switching fails, UE can fall back to initial BWP, however, it is impossible in NTN case.* * *BWP switching is coupled with data scheduling, so no dedicated BWP signalling for BWP switching only.* * *Re-synchronizaiton procedure is not required in BWP switching procedure.*   Then we think further investigation on BWP switching enhancement is needed. |
| Sony | For (1), We share the similar views with MTK, Spreadtrum that it would be helpful to prioritize discussions on associations SSB, beams and BWP. The issue (1) is impacted by the results of discussions on associations SSB, beams and BWP.  For (2), we prefer gNB dominant beam switching. Timer-based beam switching can be further studied for UE dominant beam switching. |
| Samsung | We see the current specifications support beam switching enough. But it can be further studied what could be critical in NTN scenarios. |

### Beam measurement and reporting

Moderator summary:

Companies provided your views and suggestions in their contributions on beam measurement and reporting issues.

ZTE proposes that power consumption and signalling overhead should be factored in, thus measurement can be disabled.

Signalling overhead, power consumption and measurement latency have been discussed by ZTE, Lenovo, InterDigital and Qualcomm.

ZTE proposes that measurement can be made configurable for enabling and disabling.

Lenovo proposes that a common BWP is used for beam measurements and proposes to investigate the impact of BWP switching delay for NZP-CSI-RS based beam management.

InterDigital proposes to further reduce the time gap for measuring neighbouring beams when frequency retuning is needed.

Sony proposes to reuse current R15/R16 beam measurement mechanism in NTN.

Moderator encourages companies to discuss the following item:

1. Please provide companies’ views on the beam measurement issue, power consumption, latency, signalling overhead, identified by companies’ contributions.

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| **Company** | **Comments and Views** |
| Panasonic | It seems issues related to beam measurement and reporting can be handled by gNB configuration. |
| vivo | Support to reuse Rel-15/Rel-16 beam measurement as baseline, the benefit of further enhancement should be clarified. |
| ZTE | In NTN case, the necessity of beam management is mainly determined by the movement of satellite instead of UE as legacy NR. In case of no information on UE position at gNB side (at least from RAN perspective as discussed in RAN2), the additional optimization on the measurement can be supported, e.g., report triggered by the UE, to minimize the overhead for reporting including power consumption, especially for mobile UE with limited UL link budget. |
| LG | Beam measurement in current specification can be a baseline. |
| Ericsson | We feel these are secondary issues, which depend on the progress of the topics listed in the previous sections. |
| OPPO | Beam measurement latency should be considered, e.g. if the measurement involves frequent BWP switching, how to reduce the latency and power consumption should be studied and enhancements should be supported. |
| Moderator | Beam measurement mechanism in the current spec can be the baseline and further identify the issue that may call for enhancements. |
| MediaTek | Beam measurements can be discussed based on progress on other issues are |
| Huawei | Beam measurement and reporting can be discussed later. |
| Spreadtrum | Beam measurement and reporting can be discussed later. |
| Apple | It is likely that neighbour beams used different BWPs in frequency reuse scenario. The beam measurement over different beams then involves BWP switching. We see the needs to speed up the beam measurement/reporting in NTN. |
| Qualcomm | To the least, measurement gaps may be needed since the RS may be outside of the current active BWP. |
| CATT | Due to fast beam moving, the measurement latency and measurement beam number should be further investigated. |
| Sony | Support to reuse Rel-15/Rel-16 beam measurement as baseline and prioritize discussions on associations SSB, beams and BWP. |
| Samsung | We have the same view with the intermediate summary from Moderator above. |

## Summary 1st round discussions

## Company Views (2nd round discussions)

## Summary 2nd round discussion

## GTW Agreement / Conclusion

To be added based on updated proposals following second round of email discussions

# Signalling of Polarization

## Background

The following agreements were made in RAN1#102e and RAN1#103e, respectively:

Agreement:

Potential enhancements for support of polarisation signalling in NR NTN can consider at least the following:

* Configuration of DL and UL transmit polarization including Right hand and Left hand circular polarizations (RHCP, LHCP)
* Network broadcast DL and UL transmit polarization configuration
* UE polarization capability (RHCP, LHCP, Linear)
* Dependence of polarisation signaling on deployment scenarios. For example,
  + Resource reuse mode with/without polarization for the beam management enhancement
  + Fixed polarization per cell/beam for polarization reuse and circular polarisation with intra-UE and inter-UE multiplexing (intra-UE and inter-UE) signalling

Agreement:

Indication of polarization information for DL and UL by the network is supported.

* FFS: Signalling details

In this section, we discuss the follow-up issues related to polarization signalling details.

*Potential enhancements for support of polarisation signalling in NR NTN can consider at least the following:*

* *Configuration of DL and UL transmit polarization including Right hand and Left hand circular polarizations (RHCP, LHCP)*
* *Network broadcast DL and UL transmit polarization configuration*
* *UE polarization capability (RHCP, LHCP, Linear)*
* *Dependence of polarisation signalling on deployment scenarios. For example,*
  + *Resource reuse mode with/without polarization for the beam management enhancement*
  + *Fixed polarization per cell/beam for polarization reuse and circular polarisation with intra-UE and inter-UE multiplexing (intra-UE and inter-UE) signalling*

Support of polarisation antennas depends on the UE antenna design and implementation. Polarisation can be used in the network for example for inter-cell interference mitigation or higher frequency re-use (i.e. Frequency re-use factor 4 with two carriers). The UE cannot be expected to reliably detect the used DL polarization. The network and UE need to have same understanding on support of polarisation to avoid polarisation loss of several dBs.



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| **Source** | **Related Proposals & Observations** |
| OPPO | *Proposal 5: UE reports to the gNB about its supported polarization types.*  *Proposal 6: for static multiplexing via polarizations, gNB indicates the polarization information in system information.*  *Proposal 7: for dynamic polarization assignment such as for UE multiplexing via polarization, gNB indicates the polarization information in DCI.* |
| ZTE | *Proposal 1: Polarization indication in beam level should be supported.*  *Proposal 2: Indication of polarization per beam can be implicitly supported by a mapping rule between the SSB index and the polarization.*  *Proposal 3: The supported polarization type for transmission and reception at UE side should be reported to the gNB.*  *Proposal 4: Time division multiplexing (TDM) at gNB can be used to serve UEs with different polarization capability in a given beam.* |
| vivo | *Observation 2: Circularly polarized antenna is preferred to NTN scenarios.*  *Observation 3: There are multiple types of UEs with different polarization capability in NTN beam layouts.*  *Proposal 5: The satellite beam layout with circular polarization should be prioritized.*  *Proposal 6: Enhancements on SSB transmission to support UEs with different polarization capability should be considered.*  *Proposal 7: For downlink synchronization, support to indicate the polarization information in SSB transmission.*  *Proposal 8: Support associated SSB transmission with LHCP and RHCP in TDM way.*  *Proposal 9:* *Deprioritize dynamically polarization configuration.* |
| LGE | Proposal 2. Indication of polarization mode (RHCP, LHCP) can be broadcasted via SIB where each polarization can be associated with SSB/RS indices based on pre-defined rule.  Proposal 3. For NTN, potential enhancement on BWP switching can consider at least following aspects:   * Enhancement on *bwp-InactivityTimer* including value range extension and (re)start timing, * PDSCH transmission after transmission of ACK for BWP switching command. |
| Lenovo | *Proposal 5: UE reporting of its polarization capability is supported.*  *Observation 2: Defining only a single polarization type for all frequency bands may result in reduced spectrum sharing capabilities, whereas defining multiple polarization types may result in erroneous polarization detection.*  *Proposal 6: In order to facilitate initial access procedure, one or multiple basic polarization types can be defined for different frequency bands.*  *Proposal 7: DL Polarization information can be indicated in SSBs to avoid degradation of initial cell search.*  *Proposal 8: UL Polarization information can be indicated in PRACH during initial access.*  *Proposal 9: Indication of polarization multiplexing is supported where DCI or TCI state signalling may be used for polarization-based multi-user multiplexing and single-user higher rank transmission.*  *Proposal 10: Measurement and reporting signaling for polarization is needed for efficient beam switching and handover. CSI-RS may be used for polarization measurements.* |
| Sony | Observation 4: The UE capability on the supported polarization mode is necessary for the NTN network to use the polarization domain. Such a capability can be either reported explicitly by the UE or implicitly through the UE measurement and reporting of the DL RS on two orthogonal polarizations.  Observation 5: The gNB can configure multi-user multiplexing on the polarization domain based on UE capability.  Proposal 4: UE polarization capability should be reported to the gNB, where the UE supported polarization mode can include linear polarization, circular polarization and adaptive polarization.  Proposal 5: Multi-user multiplexing on the polarization domain based on UE capability is supported.  Proposal 6: Beam management, e.g., spatial relation, in NTN network can include polarization aspect. |
| Ericsson | Observation 5 In some cases, a UE cannot be expected to reliably detect the used DL polarization.  Proposal 5 Support broadcast signaling that allows a gNB to indicate the gNB’s DL transmit polarization mode and UL receive polarizations mode to UE.  Proposal 6 Support signaling that allows the gNB to configure a UE’s polarization modes including the UE’s receive polarization mode in the DL and the UE’s transmit polarization mode in the UL.  Proposal 7 NTN UE should report its polarization capability (RHCP, LHCP, Linear) to the network. |
| Huawei, HiSilicon | *Proposal 4: At least cell-level and beam-level polarization indication for NTN should be supported.* |
| THALES | Proposal 1 To increase the per-beam bandwidth while ensuring excellent interference isolation between beams, other frequency separation techniques such as polarization re-use scheme should be considered  Observation 3 Circular polarization can be used to double the cell capacity |
| Panasonic | Proposal 2: Signaling for the following two usages of circular polarization should be supported.   * Polarization reuse for inter-cell/beam interference mitigation * Polarization multiplexing for throughput improvement   Proposal 3: For operation with polarization reuse, information on satellite beam level polarization should be indicated. For the signaling design, polarization to be used at least for initial access, polarization to be used for SSB/CSI-RS measurement and polarization for target beam/cell should be taken into account.  Proposal 4: For operation with polarization multiplexing, information on the polarization should be indicated in DCI for scheduling PDSCH/PUSCH. |
| NOKIA | Proposal 3: Use broadcast transmission to provide the default polarisation indication for DL and UL.  Proposal 4: Define a network configured basic polarization mode for DL and UL operation which is used for initial access.  Proposal 5: Clarify if signalling of polarization mode using RRC signalling for CONNECTED mode UEs can really be supported in the transparent paylod scenarios. |
| Apple | *Proposal 4: The polarization information is configured in a beam specific manner and consider using SIB to signal this polarization information.* |
| Qualcomm | Proposal 11: Consider at least signalling of polarization per BWP. |
| CATT | 1. For the UEs supporting both RHCP and LHCP, polarization reuse configuration in the NTN is beneficial, while for the linear polarization UEs and single circular polarization UEs, network polarization reuse scheme is not expected. 2. The single circular polarization UEs cannot work in the different circular polarization beams, so that reporting the polarization capability is useless. 3. It is not necessary to report the circular polarization mode to the network for the dual circular polarization UEs. 4. For the linear polarization UEs, only reporting the polarization capability is not sufficient to help gNB to conduct proper operation. 5. The polarization reuse scheme should be optional in NTN. 6. The polarization indication of network should be optional in the signalling design. 7. Reporting UE polarization capability is not supported. |

Moderator summary:

1. UE reporting its supported polarization type: OPPO, ZTE, Lenovo, Sony, Ericsson
2. Polarization usage
   1. Inter-cell/beam interference mitigation, discussed by Panasonic
   2. Throughput improvement via polarization multiplexing, discussed by THALES, Panasonic, OPPO
3. Polarization indication or configuration
   1. explicit indication
      1. gNB broadcast polarization information, proposed by OPPO, LGE, Ericsson, Apple
      2. gNB configures UE-specific polarization configuration for DL and UL, proposed by Sony (include polarization in TCI), Ericsson, Panasonic (in DCI for multi-user mux), OPPO, NOKIA, Qualcomm
   2. implicit indication
      1. mapping with SSB index, proposed by ZTE, vivo, LGE

## Companies Views (1st round discussions)

Moderator encourages companies to discuss the following item:

1. Views on supporting polarization type reporting from UE to network
2. Companies to provide views on the target usage of polarization, e.g. inter-beam interference mitigation, polarization multiplexing to throughput improvement.
3. Companies to provide views on the polarization signalling, including explicit signalling vs. implicit signalling.

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| **Company** | **Comments and Views** |
| Panasonic | 1. Even UE with single linear polarization antenna can also receive and transmit circular polarization with 3dB de-polarization loss. Therefore, there seems no need for UE to report polarization type. 2. Signalling for both use cases, polarization reuse for inter-cell/beam interference mitigation, and polarization multiplexing for throughput improvement, should be supported. 3. the following signaling design may be considered as a starting point:   SIB contains information on the polarization for each SSB in the serving cell. This is used for UE in initial access.  For beam management, polarization information is included in the TCI state IE, explicitly in the IE or linked to the QCL source. Polarization of NZP-CSI-RS for beam management can be indicated by referring to the TCI state.  For RRM measurement, polarization information is included in the measurement object IE (e.g. as a CSI-RS configuration in the measurement object IE).  For signaling for polarization multiplexing, existing DCI indication for MIMO in NR Rel.15/16 can be reused, e.g. using antenna port indication and TPMI indication, to have commonality with legacy NR as much as possible. |
| vivo | Further study polarization type reporting from UE to network, since the benefit is unclear.  The target usage of polarization should be focused on inter-beam interference mitigation. Since the coverage should be the main bottleneck in NTN, the necessity of using polarization for multiplexing (intra-UE/inter-UE) needs to be further clarified.  For the polarization signalling, before we talk about explicit signalling and implicit signalling, the more important issue is when the polarization should be indicated. In our view, SSB transmission occasion is a candidate and suitable way. |
| ZTE | The reporting of polarization from UE side is beneficial to the gNB from scheduling perspective as implementation, e.g., whether to reallocated to the resource for each UE or scheduling UEs with same polarization in TDM manner if multiple UEs with fixed polarization are within the beam center. From specification perspective, no additional specification impact is needed except for the adding new information in existing signalling.  W.r.t the target usage of polarization, which is mainly implementation issue, the gNB can do corresponding optimization on either scheduling (e.g., multiplexing) or beam/polarization indication (e.g., to mitigate the interference). Surely, the latter one is 1st priority as polarization will be reused as another factor to support the frequency reuse factor = 4.  From gNB perspective, the beam layout along with polarization is semi-static allocated. In this way, implicitly indication is preferred to reduce the additional overhead. |
| LG | 1) We also think the benefit of reporting polarization type is not clear.  2) Interference mitigation can be considered as first priority.  3) Polarization mode signalling can be broadcasted by gNB via SIB for the initial access. In the perspective of overhead reduction, association with SSB and polarization mode can be further considered. |
| Ericsson | On 1), NTN UE should report its polarization capability (RHCP, LHCP, Linear) to the network.  On 2), both interference mitigation and spatial multiplexing are valid usage scenarios that find applications in practice.  On 3). Explicit signaling.   * Support broadcast signaling that allows a gNB to indicate the gNB’s DL transmit polarization mode and UL receive polarizations mode to UE. * Support signaling that allows the gNB to configure a UE’s polarization modes including the UE’s receive polarization mode in the DL and the UE’s transmit polarization mode in the UL. |
| Thales | 1. Support polarization type (RHCP, LHCP, Linear) reporting from UE to network 2. Both inter-beam interference mitigation and polarization multiplexing schemes can be considered. 3. Support at least explicit polarization mode signalling for UE UL TX and DL RX. |
| OPPO | 1. Support polarization type reporting to network. 2. NTN shall support to use polarization to reduce the inter-beam interference and polarization multiplexing. 3. Support explicit signalling for polarization type, including gNB Tx polarization and Rx polarization. This can be signalled in system information or RRC message. |
| Moderator | Quick summary  Slightly majority views to support UE polarization capability (RHCP, LHCP, Linear) reporting.  Majority views to support both interference mitigation and spatial multiplexing are valid usage scenarios. Some other views think high priority should be given for interference mitigation.  For polarization indication, vivo asks when this indication should be conducted by the gNB? From FL understanding, this indication should be given since initial access. Other opinions are welcome to add here.  Majority views to support explicit indication, e.g. UE Tx polarization and UE Rx polarization. |
| Huawei | 1. Polarization type report may not needed if beam specific for cell specific polarization are applied. It will be more complex for gNB to adjust the polarization according to different UE capability. 2. Polarization can be used for inter-beam interference mitigation and also applied among SSB for inter cell interference mitigation 3. Support explicit signalling of polarization including either cell-level and beam-level indication. |
| Spreadtrum | 1. Polarization type report needs more discussion. 2. The target usage of polarization include inter-beam interference mitigation and polarization multiplexing. 3. Support explicit signalling of polarization. |
| Apple | 1). The motivation of UE reporting its polarization capability is unclear in case the polarization signaling is broadcast.  2). We think the inter-beam interference mitigation is the main target usage of polarization  3). We support the explicit signaling of polarization, in terms of system information. |
| Qualcomm | 1. The motivation of UE reporting its polarization capability is unclear. 2. Depending on the usage of polarization, different signalling mechanisms of polarization may be needed. For polarization multiplexing, signalling of polarization may not be necessary. For inter-beam interference mitigation, it is beneficial to signal the polarization of each beam. However, this would require dual-polarization capable antennas in case of circular polarization. |
| CATT | Reporting the UE polarization mode is not justified. Regardless UE reporting or not, gNB can’t change the polarization mode of network. UE can adapt its polarization mode based on gNB indication or via blind signal detection. In this sense, no need to report UE polarization type. |
| Sony | For (1) adopting wrong polarization between gNB and UE may result significant performance degradation. For example, if the DL signal is on LHCP while the UE is receiving with RHCP, the UE will completely miss the DL signal. In addition, knowing the UE capability on polarization can enable the network to multiplex multiusers over polarization domain. Therefore, support UE report polarization type and polarization capability are critical for NTN network.  For (2) polarization can be used for inter-beam interference mitigation and multi user polarization multiplexing and MIMO, as well as improve the cell search performance when the polarization information is associated with SSB.  For (3) explicit signalling is preferred. |
| Samsung | We think signalling by SIB for indication of polarization is enough. The benefit of UE-specific polarization is not clear. |

## Summary 1st round discussions

## Company Views (2nd round of discussions)

## Summary 2nd round discussion

## GTW Agreement / Conclusion

To be added based on updated proposals following second round of email discussions

# Additional Aspects

Aspects on NTN discussed by one or two companies are discussed in this section.

## RACH Enhancements

Nokia proposed to enable additional SCS scaling factors for all formats defined in TS 38.211 table 6.3.3.1-2 and add one new format (C1) and support restricted set type A for formats defined in TS 38.211 table 6.3.3.1-2. Nokia observed that as GNSS is external to 3GPP, the standard cannot dictate how the UE implements its GNSS solution nor the system chosen (GPS, GLONASS,Galileo, Others). The precision and availability provided by different systems may vary significantly. The full-reliance on GNSS for synchornization and Random Access procedures leaves the 3GPP system implementation dependent on third part systems. Nokia proposed that NTN systems must contain a fall-back conservative solution that allows UE to access the network in case of faulty or malfunctioning GNSS systems.

Samsung observed that a GNSS-aware UE can determine the time and frequency pre-compensation that it should apply when transmitting a PRACH preamble, which improves preamble detection performance for all GNSS-aware UEs. The PRACH guard time for GNSS-aware UEs can be smaller than the PRACH guard time for GNSS-challenged UEs. If PRACH preamble transmissions from GNSS-aware UEs do not interfere with PRACH preamble transmissions from GNSS-challenged UEs, preamble detection performance for all GNSS-challenged UEs improves. Samsung propose that gNB can assign separate PRACH resources to GNSS-aware UEs and GNSS-challenged UEs.

LG propose that if enhanced PRACH formats and/or preamble sequences are necessary and supported in Rel-17 NTN, the option with simple modification, such as a single Zadoff-Chu sequence based on larger SCS and repetition number, is preferred.

Qualcomm proposes transmit diversity for PRACH transmission with format 2, where the antenna switching is applied for the first half and the second half of the PRACH. The simulation shows about 2 dB gain at 1% miss detection rate.

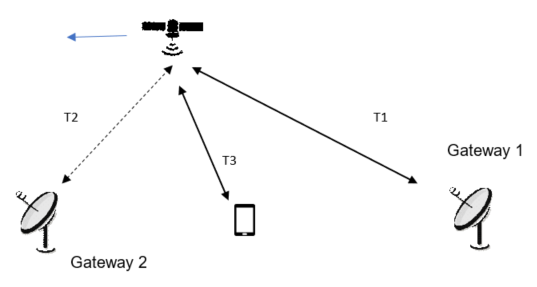
Switching Point

CP/2

***FL recommendation on RACH enhancements: the needs for RACH enhancement can be further discussed to reach potential consensus on the PRACH enhancement. Companies are encouraged to provide their views.***

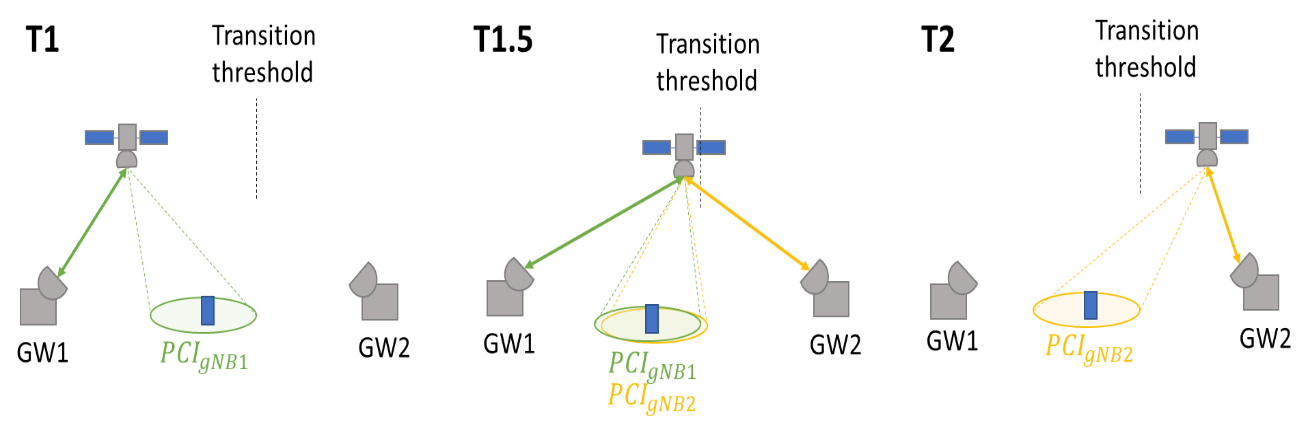
## Feeder link switch

Feeder link switch occurs when the Gateway changes due to satellite moving from coverage of one Gateway into coverage of another Gateway as illustrated on Figure below.



Soft Feeder link switch:

In soft feeder link switch, the satellite can simultaneously support two feeder links is illustrated in Figure below.



Interdigital observe that soft feeder link switch has less impact to current specification propose Rel-17 than a hard feeder link switch. Soft feeder link switch can support unique PCIs for cells from the source and target gNBs to be simultaneously relayed through the same satellite. The UE can distinguish the cells by different synchronization raster points for CD-SSBs. Interdigital propose to support soft feeder link switch for transparent LEO NTN

Hard Feeder link switch:

In Hard feeder link switch, the satellite only support one feeder link at a time.

CATT proposed that the feeder link hard switch procedure should be based on group switching with accurate time control. In order to support hard feeder link switching, the following enhancements can be considered:

* Before handover, network should inform all UEs to stop UL transmission at one time point, and restart RRC connection in a new cell after a timer expired.
* The network should broadcast the propagation delay difference and UL TA offset of new targeted cell.
* PRACH parameters configuration need to be extended to support massive user handover, including ssb-perRACH-Occasion, Msg1-FDM, PRACH Mask index.

Interdigital observe that a hard feeder link switch can result in all connected mode UEs served by the satellite attempting mobility simultaneously, leading to RACH collisions, RLF and service interruption due to cumulative delay in RRC re-establishment signalling. Synchronizing UEs to perform HO without collision introduces complexity and additional signalling in the HO command. Providing assistance data to aid RRC re-establishment may assume a land-based connection between source and target gNBs, which cannot be guaranteed.

Other RAN1 aspects of feeder link switch:

Nokia propose that RAN1 define the feeder and service link type of amplification for gNB interpretation of measurement reports and configuration of UE uplink transmit power control with three options considered:

* Constant gain: The combined receive and transmit gain is a constant, independent of the received signal.
* Constant Emitted Isotropic Radiated Power (EIRP): The satellite will adjust the combined receive and transmit gain based on the received signal and a target EIRP to make the feeder link gain equal to one.
* Constant power at receiver: The satellite will attempt to compensate for the radio channel.

Nokia observes that transparent satellite can be analogue RF repeater or sample and forward a digital version of the analogue transmissions. The gNB may in principle compensate for the timing advance and Doppler on the NTN-GW – satellite link, which implies the UE only needs to handle the service link. Nokia propose that RAN1 clarifies that the satellite does not terminate the Uu interface. The gNB location relative to the NTN-GW may impact the NTN user experience and propose RAN1 defines an assumption of the maximum tolerable gNB – NTN-GW delay.

Xiaomi propose the change of the timing due to the switch of feeder link switch can be managed at the gNB side.

***FL recommendation on feeder link: According to the NTN work plan, RAN2 plans to send LS to RAN1 about the feeder link switch design alternatives. RAN1 can wait for RAN2 guidance before discussing specific RAN1 aspects requiring potential enhancements and specifications.***

## DL Synchronisation, System Information Acquisition

Qualcomm proposes different SIBs design based on the system information updating rate.

Samsung observed that for a spot beam size that exceeds 250 km, a BS may need to perform a multi-valued Doppler pre-compensation; e.g. it may need to group distinct sets of SSBs using distinct Doppler values for pre-compensation. Indication for multi-Doppler pre-compensation pattern on DL benefits idle UE cell reselection, connected UE handover and connected UE data channel reception. The gNB/satellite can apply different values of Doppler pre-compensation to different SSBs. Samsung proposes that the BWP configuration is extended to indicate the amount of frequency offset to adjust the PRB grid with respect to the default BWP, as the experienced Doppler shifts at different spot beams are different.

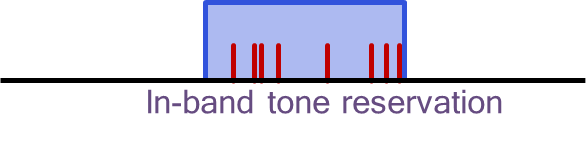
|  |  |  |
| --- | --- | --- |
| fc (GHz) | spot beam size (km) | maximum Doppler difference between UEs (kHz) |
| 2 | 50 | 4.185 |
| 2 | 200 | 15.87 |
| 2 | 250 | 19.25 |
| 2 | 300 | 22.33 |
| 2 | ~ 600 | ~ 45 |



## PAPR

Qualcomm observed that a tone reservation method denoted by peak reduction tones (PRTs) can reduce Raw Cubic Metric of the CP-OFDM waveform in the NTN downlink by about 0.4 dB - 0.6 dB in Raw Cubic Metric reduction compared to hard-clipping power amplifier model for QPSK and 256QAM. Higher reduction for PAPR in 2 dB – 3.8 dB also observed. Tone reservation can increase the net transmit power of the CP-OFDM waveform in the NTN downlink by up to 1.5 dB.

CAICT tested the DFT-s-OFDM signal both in lab and on orbit. They observed that the performance of DFT-S-OFDM signals in the satellite channel scenario meets the design and simulation expectations

## Power Control and PUSCH coverage

Samsung proposed that open loop power control, UE should be allowed to predict its own transmission power not only based on DL measurement, e.g., pathloss measurement but also other available information, such as gNB ephemeris and UE trajectory. Samsung proposed closed loop power control should be supported in NTN and a mechanism to disable closed loop power control should be considered.

Qualcomm proposed to support autonomous reduction of MCS for PUSCH at least for cases when UE is power limited and to study the exact triggering condition and indication of the reduced MCS

Vivo presented link budget for handheld dvice with antenna gain -5 dBi based on the link budget parameters in TR 38.821, relevant link budget was evaluated to figure out the worst-case achievable SNR for handheld devices as follow in Table 1. It should be noted that antenna gain of -5 dBi is preferable for commercial smart phones, instead of antenna gain of 0 dBi.

**Table 1. Link budget results for Set-1 and Set-2**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Satellite | Elevation angle | | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 |
| Set-1 | DL | LEO-600km | -3.615 | -0.671 | 1.607 | 3.338 | 4.634 | 5.575 | 6.214 | 6.585 | 6.707 |
| LEO-1200km | -1.810 | 0.400 | 2.220 | 3.679 | 4.811 | 5.653 | 6.234 | 6.575 | 6.687 |
| UL | LEO-600km | -10.454 | -7.510 | -5.233 | -3.501 | -2.205 | -1.264 | -0.625 | -0.254 | -0.132 |
| LEO-1200km | -14.649 | -12.439 | -10.619 | -9.160 | -8.028 | -7.186 | -6.605 | -6.264 | -6.152 |
| Set-2 | DL | LEO-600km | -9.615 | -6.671 | -4.393 | -2.662 | -1.366 | -0.425 | 0.214 | 0.585 | 0.707 |
| LEO-1200km | -7.810 | -5.600 | -3.780 | -2.321 | -1.189 | -0.347 | 0.234 | 0.575 | 0.687 |
| UL | LEO-600km | -16.454 | -13.510 | -11.233 | -9.501 | -8.205 | -7.264 | -6.625 | -6.254 | -6.132 |
| LEO-1200km | -20.649 | -18.439 | -16.619 | -15.160 | -14.028 | -13.186 | -12.605 | -12.264 | -12.152 |

Furthermore, vivo provided LLS results for PUSCH VoIP that shows a gap between minimum required SNR and the worst-case achievable SNR for handheld devices in NTN, where PUSCH VoIP is based on 20 slots (e.g. 20ms in 15kHz SCS) aggregated VoIP transmission to enhance the performance, instead of maximum 16 in current specification. In the simulation result, it is apparently observed that there is a significant gap between minimum required SNR and the worst-case achievable SNR. For Set-1 satellite with LEO 1200km orbit altitude, there is a great obstacle to match the minimum required SNR, not to mention Set-2.

## Air To Ground

CMCC proposed “implicit compatibility to support HAPS and ATG scenarios” in the WID means the enhancements for NTN can also be applicable for HAPS and ATG, although we do not need to discuss the enhancements specifically for HAPS and ATG. In principle,

* If there are several potential solutions for NTN, and some of them are more essential / important / applicable for ATG / HAPS, then these solutions should be prioritized.

CMCC proposal: Extend the value range of K1 from (0..15) to (0..31), while keep the bit size of PDSCH-to-HARQ\_feedback timing indicator field in DCI unchanged.

## Satellite ephemeris

CMCC proposed: For serving satellite ephemeris broadcast by the gNB, at least support instant state vectors format (Option 2).

## Companies views (1st round discussions )

Companies are invited to comment on Additional aspects.

|  |  |
| --- | --- |
| **Company** | **Comments and Views additional aspects** |
|  |  |
|  |  |

## Summary 1st round discussions

## Companies views (2nd round discussions)

## Summary 2nd round discussion

## GTW Agreement / Conclusion

To be added based on updated proposals following second round of email discussions

# References

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