3GPP TSG RAN WG1 Meeting #102e R1-200XXXX

e-Meeting, August 17th – 28th, 2020

Agenda Item: 8.4.4

Source: MediaTek Inc.

Title: Summary 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#102e. 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*

Air to Ground networks topic is also included as it is a scenario in scope of the objectives of the WID.

# Random Access

## Scenarios of UE with GNSS Capability but without pre-compensation Capability

It is assumption in Rel-16 NR NTN WI that UE with GNSS capability can determine and pre-compensate satellite delay and Doppler. This requires knowledge of long-term satellite ephemeris or real-time satellite position and velocity. With this assumption, the legacy RACH can be re-used for NR NTN.

Ericsson proposed to identify scenarios where UE with GNSS capability cannot determine and pre-compensate satellite delay and Doppler [17]. Intel, Panasonic proposed not to discuss RACH enhancements as not needed assuming GNSS capability for UE pre-compensation [9, 14]. MediaTek, ZTE discussed indoor UEs without GNSS coverage and whether NR NTN link budget is sufficient in this scenario, ZTE further proposed enhancement on the PRACH formation to improve the link budget [4, 10].

For ATG NR TDD in 5 GHz band, rel-15 RACH may not work without UE pre-compensation of aircraft delay and Doppler of up to 1 ms and ±11 kHz respectively.

MediaTek proposed NR ATG without GNSS coverage should first discuss special ATG UE using aircraft GNSS antenna, or direct access for normal phones with poor in-cabin GNSS reception [4].

Huawei observed there is no need to enhance the preamble design unless the UL frequency and timing error estimated based on UE location and satellite position/velocity exceeds the tolerance of the existing NR preambles [1].

## RACH design Options

In case pre-compensation of timing and frequency offset at UE side for UL transmission cannot be assumed, options considered in Rel-16 NR NTN SI for enhanced PRACH formats and/or preamble sequences and companies’ preference are summarized below:

• Option 1: A single Zadoff-Chu sequence based on larger SCS, repetition number. Additional usage of CP and Ncs can be further determined in normative work ZTE, LG, Fraumhofer [10, 15, 5]

• Option 2: A solution based on multiple Zadoff-Chu sequences with different roots: Ericsson, MediaTek, ZTE [17, 4, 10]

• Option 3: Gold/m-sequence as preamble sequence with additional process, e.g., modulation and transform precoding

• Option 4: A single Zadoff-Chu sequence with combination of scrambling sequence.

If RAN1 can determine usefulness of scenarios where a RACH enhancements will be needed, normative work should aim to minimize impact on specifications, implementation complexity, and testing in device and Network. RAN1 should further discuss and make a decision on best all-round option that meet performance requirements for UL timing and frequency synchronization, minimize potential normative work and implementation and testing in UE and network.

***Potential proposal#2-1: Identify and discuss potential scenarios where GNSS-equipped UEs cannot perform timing and frequency pre-compensation for uplink synchronization.***

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| **Company** | **Comments and Views on scenarios of UE with GNSS capability but without pre-compensation capability** |
| Panasonic | We prefer to focus on NTN scenario with GNSS coverage in Rel.17, then no PRACH enhancement.  |
| Ericsson  | Support this proposal |
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# Feeder Link Switching

## Feeder Switch Methods

As satellite moves, the feeder link may need to be switched. There are options for the feeder link switching for transparent payload:

Feeder link hard switch procedure for “transparent LEO, Architecture Option 1, different gNBs” [3, section 8.7.1.1.1]:

* Switching based on accurate time control: The old feeder link serves the satellite until T1 and the new feeder link begins to serve the satellite from time T2. The Hand Over (HO) command is sent to all the UEs before T1, e.g. Conditional HO, which initiate the handover procedure after T2 based on an activation time included in the HO command.
* Switching based on conditional RRC re-establishment: the network to provide assistance information (e.g. next cell identity and/or reestablishment conditions) to trigger UE RRC reestablishment instead of Conditional HO based on accurate time control.

Feeder link soft switch procedure for transparent LEO NTN, Architecture Option 1, same gNB [3, section 8.7.1.1.1].

* The transparent satellite is served before and after the feeder link switch by the same gNB. Both feeder links are connected to the same gNB, but through different NTN-GWs. With two feeder link connections serving via the same satellite during the transition, the gNB can transmit the DL reference signals without interruption to keep the cell "alive". There may be no need of a HO if the security keys of gNB can be kept in the UE. Re-configuration of gNB may be avoided if the same configuration is used before and after the switch. The switchover relies on the temporary overlap of cells from the gNBs located at the old and the new NTN GWs.

Ericsson made observation that legacy layer 1 specification already supports transmitting multiple cells on different time/frequency resources. The satellite supports simultaneous transmissions of both gNB’s signals (which use different PCIDs) during the switch to enable a smooth handover. Hence, for a soft feeder link switch scenario, there are no major RAN1 issues for the solution identified in TR 38.821. Satellites typically have the capability to connect to multiple gateways by using multiple antennas. The scenarios where the same gNB is connected to multiple satellite gateways or where the satellite can only support one feeder link at a time should be discussed in RAN2 first [17].

InterDigital observed that 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 [19].

Nokia proposed RAN1 clarifies impact of feeder link switch and benefit of signalling assistance information for imminent switch events [16]. CATT makes proposal for signalling assistance information to support hard feeder link switch [7]:

* 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, UL TA offset, Doppler pre-compensation information of new gateway.
* PRACH parameters configuration need to be extended to support massive user handover, including ssb-perRACH-Occasion, Msg1-FDM, PRACH Mask index.

Xiaomi observed that for the case that full TA compensation is applied at the UE side, UEs need to be informed of the timing change due to the feeder link switch, this will cause much signalling overhead. For the case that differential TA compensation is applied at UE side, UEs only need to adjust its timing based on the TA offset on its service link. The timing change due to the feeder link switch can be managed at gNB side [18].

Huawei observed that there are several potential NTN scenarios for feeder link switching for transparent satellites as follows [1]:

* Integrated gNB/Gateway with one feeder links or multiple feeder links
* Separate gNB/Gateway with one feeder links or multiple feeder links

## Feeder link delay and Doppler

As satellite moves, the feeder link may need to be switched. As each feeder link experience its own specific delay, delay drift and Doppler, when the feeder link is switched it can be expected that the delay and Doppler conditions over the new feeder link will be different from that in the old feeder link.

MediaTek considered options for mitigation of Doppler over feeder link [4]

- Feeder link Doppler compensation error requirement

- GW post compensation of feeder link Doppler

MediaTek considered options for mitigation of Delay drift [4]

- Feeder link delay drift compensation error requirement

- gNB indication of feeder link delay drift

- Gateway/gNB compensation of feeder link delay drift

***Feeder link delay and Doppler will be discussed in timing relationship enhancements AI 8.4.1 and UL synchronization AI 8.4.1***

***Potential proposal #3-1: RAN2 discuss first scenarios for soft feeder link switch and hard feeder link switch and identify potential issues to be discussed in RAN1 if any***.

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| **Company** | **Comments and Views on Feeder Link Switch Methods** |
| Panasonic | Support proposal #3-1 |
| Ericsson  | Support this proposal |
| Sony | Support proposal #3-1 |
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# Beam Management, BWP, Signalling of Polarization

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. A number of companies have made proposals and observations for enhancements to both procedures covering aspects of cell/beam/frequency planning, SSB arrangements, and enhancement of signalling for initial access, efficient switching between satellite beams, measurements and reporting. In NR specifications, DL BWP configuration contains configurations about CORESETs and search spaces. A UE may first use an initial BWP#0 for initial cell access as indicated in initialDownlinkBWP on SIB1 or via dedicated signalling. A default DL BWP can also be configured. The initial BWP#0 is used to transmit time multiplexed SSBs including common channel, e.g., paging on DL and PRACH on UL. In NR specifications, DCI signalling is used to indicate BWP switching, where the BWP switching in UL and DL is separately configured. The UE can fall back to initial BWP if the switching fails.

In legacy NR specifications, a device needs first to switch from the serving BWP#x to initial BWP#0. Assuming device makes measurements on a BWP that is different from the BWP of the current serving satellite beam, device will need to retune its frequency for measurements and prepare for the frequency compensation to report measurements frequently – i.e. every 10 seconds typically in LEO scenario with earth-moving beams (the dwell time for earth-fixed beam can typically be several minutes). Qualcomm, ZTE, and MediaTek discussed efficient signalling mechanisms for the beam measurement to reduce signalling overhead.

In legacy NR beam management framework, to adjust the DL Tx-side beam, the gNB relies on the CSI reporting from UE, e.g. L1-RSRP. UE needs to measure SSB or NZP-CSI-RS of its serving beam and neighboring beams and report measurements. The gNB indicate the serving beam via Transmission Configuration Index (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. Ericsson [17], Panasonic [14] discussed aspects of TCI state for NTN.

Association options between beam, SSB and BWP where discussed by several companies – Ericsson [17], Qualcomm [22], ZTE [10], MediaTek [4]. ZTE discussed association option with polarisation.

Thales observed that single NR cell per satellite beam and single NR beam cell can be used as a baseline without beam management [2].

## Beam Management

Ericsson [17], MediaTek [4], Thales [2], Sony [6], OPPO [11], Lenovo [8], CAICT [23] discussed configuration where a satellite cell uses an anchor beam transmitting BWP#0 and comprising multiple spotbeams each associated with a BWP dedicated for data transmission. This type of configuration to enable soft frequency reuse could be supported with NR specifications and is up to network implementation. System capacity bottleneck for initial cell access and paging and potential enhancements could be further discussed. ZTE discussed a common BWP#0 overlapping partially with different dedicated BWPs for each beam [10].

 

Intel observed that polarisation and frequency reuse for different beams can be implemented using Rel. 15 NR beam management. SSB corresponding to different beams can be transmitted in the same frequency band and multiplexed in time domain while other physical channels can be transmitted in different parts of the frequency band by using different frequency domain resource allocation for the UEs in different beams. Alternatively, it can be assumed that transmission with different beams corresponds to different BWP or different component carriers. Beam management enhancements in Rel. 17 feMIMO WI could be used for NTN [9].

Qualcomm made a number of proposals for Cell/Beam/frequency planning, SSB Arrangements and signalling enhancements. Assuming a cell consists of multiple satellite beams with different frequency intervals, a bandwidth part (BWP) is associated with each of the frequency intervals. [22]:

* Support both one-beam-per-cell mapping and multiple-beams-per cell mapping with different SSB arrangements. Four options are considered, where cell/beam/frequency planning Opt 1 is supported by the current NR specification. Opt 4 is the building block for both Opt 2 and Opt 3. [22].



* 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.
* For multiple SSBs transmitted in the same frequency with SSB arrangement Alt.1, support different initial BWPs for the SSBs and down select among the following design options:
	+ Design 1: Corset 0’s of the SSBs can occupy different frequency intervals.
	+ Design 2: CORSET 0’s and SIB1’s of the SSBs are in the same frequency interval.
* For multiple SSBs transmitted in the same frequency with SSB arrangement Alt.2, the UE can follow the procedure in the existing NR specification.
* In order to support frequency reuse of factor less than 1, different satellite beams must be allowed to have different associated BWPs, such as initial BWPs.
* Support signalling of the configuration of initial BWPs and CORSET#0 for satellite beams other than the serving satellite beam.

The following observation were made on SSB arrangements alternatives:

**Alt 1:** All SSB transmissions in a cell occupy a same frequency interval (which may be fully contained in a BWP or straddle two BWPs)

* Pros: there is a smaller number of potential SSB frequencies for the UE to search for, and they can be placed in a sparse synch raster, which reduces initial access time
* Cons: A satellite beam needs to be tuned from the BWP that it uses for data communication to the same SSB frequency periodically. This may increase the hardware complexity of the satellite.

**Alt 2:** The SSB transmission in a satellite beam of a cell is within the BWP associated with the satellite beam

* Pros: A satellite beam does not need to tune away from its BWP to transmit an SSB, and this avoids the increase in hardware complexity.
* Cons: The number of SSB frequencies will be larger than in Alt 1, and the SSB frequencies need to be placed on a dense synch raster, leading to an increase in the initial access time.

MediaTek [4], CATT [7], OPPO [11], Xiaomi [18] support SSB arrangement Alt 2. with an association between an SSB index and a BWP index in beam-specific BWPs to mitigate the signalling overhead in DCI or RRC signalling for changing UE’s active BWP configuration.

Panasonic discussed number of SSBs for NTN. Rel-15/16 NR specified up to Lmax SSBs in a cell, where Lmax can be 4, or 8 for FR1 and 64 for FR2. If the same limitation is applied to NTN for FR1, increasing the cell size by transmitting multiple SSBs may need to be done with larger number of SSBs [14].

**Potential proposal #4-1: Discuss scope of studies and potential enhancements of SSB arrangements for beams and BWPs in NTN:**

* **Support both one-beam-per-cell mapping and multiple-beams-per cell mapping**
* **Support satellite beam specific initial BWPs**
* **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.**
* **For multiple SSBs transmitted in the same frequency with SSB arrangement Alt.1, support different initial BWPs for the SSBs and down select among the following design options:**
	+ **Design 1: Corset 0’s of the SSBs can occupy different frequency intervals.**
	+ **Design 2: CORSET 0’s and SIB1’s of the SSBs are in the same frequency interval.**
* **Support signalling of the configuration of initial BWPs and CORSET#0 for satellite beams other than the serving satellite beam.**
* **Support an association between association between an SSB index and a BWP index in beam-specific BWPs.**
* **Support larger number of SSBs**

Ericsson proposed to discuss the following for beam management [17]

* NR beam management framework with TCI state and spatial restrictions within the same satellite or support the switching of the service links associated with different satellites
* Support the switching of the service links associated with different satellites including Signaling of the ephemeris for UEs in RRC connected and timing of switching to UEs in RRC idle and RRC inactive

Panasonic discussed the UE should report its location once the RRC connection is established. Based on this location information, gNB can predict the UE’s relative location to the satellite in the LEO moving cell scenario and adjust the serving beam for the UE via indication of “TCI state” via DCI or MAC CE. It is further discussed that TCI state of CORESET is activated according to a preconfigured pattern depending on the UE location and satellite ephemeris information, and can be configured by RRC to reduce Signaling overhead for beam indication (e.g. via MAC CE and DCI) [14].

Thales proposed bandwidth part indicator field on DCI should be unchanged. MAC CE transmission configuration indication (MAC CE TCI) can be used to indicate and update serving beam and implicitly the Beam-specific BWP [2].

**Potential proposal #4-2: Discuss and study potential enhancements of TCI state indication for beam management in NTN:**

* **NR beam management framework with TCI state and spatial restrictions within the same satellite or support the switching of the service links associated with different satellites**
* **MAC CE transmission configuration indication (MAC CE TCI) can be used to indicate and update serving beam and implicitly the Beam-specific BWP**
* **Support the switching of the service links associated with different satellites including Signaling of the ephemeris for UEs in RRC connected and timing of switching to UEs in RRC idle and RRC inactive**
* **Support activation of TCI state of CORESET according based on the UE location and satellite ephemeris information**

ZTE proposed measurement-less and group switching for beam management to improve the performance [10].

Sony [6], Lenovo [14] discussed UE beam measurements on multiple BWPs using CSI-RS in beam-specific BWP. Sony observed this can minimize measurement delay and Signaling overhead, and improve the accuracy of the measurements as all the beams are measured on their associated BWP. Lenovo observed this avoids configuration of NZP CSI-RS for beam management in a common narrow band BWP for all geographical areas/footprints re-using the behaviour in legacy NR with additional overhead and need for UE to monitor two active BWPs in a geographical area, one for beam management and one for DL/UL transmission/measurement/reporting. For aperiodic NZP CSI-RS, BWP switching delay should be considered when determining the time domain offset between the triggering DCI and the NZP CSI-RS for beam management at different BWPs.

**Potential proposal #4-3: Discuss scope of studies and potential solutions for measurement mechanisms for beam management in NTN:**

* **Measurement-less and group switching for beam management**
* **Measurements on multiple BWPs using CSI-RS in beam-specific BWP**

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| **Company** | **Comments and Views on Beam Management** |
| Panasonic | Potential proposal #4-1: Agree to discuss. But, if the number of SSBs are not increased, enhancement for SSB arrangement would not be needed. Potential proposal #4-2: current mechanism for TCI state indication would be workable with potentially increased UE power consumption and signalling overhead for earth moving cell scenarios. Therefore, we propose UE location based beam switch. Potential proposal #4-3: beam measurement can be reduced by UE location based beam switch.  |
| Ericsson | There are 3 proposals with many bullets. It is a bit difficult to comment. Our general comment is that BM is well supported by existing NR specification already and continues to be enhanced in Rel-17 feMIMO. It is important to ensure NR NTN features to have synergies with NR terrestrial solutions as much as possible. Diverging from terrestrial features would much reduce the chance of NR based NTN being developed.Regarding Proposal #4-1:* Bullet 1: One beam per cell (as used in many satellite systems today) should be the baseline to have a working NTN system in Rel-17. The multi-beam per cell is an enhancement, without which the system is not broken.
* Bullet 2: Initial BWP is cell specific. Deviating from this fundamental assumption will imply significant specification changes, overwhelming implementation and testing efforts.
* Bullet 3: Alt. 1 is the fundamental design of NR. Deviating from this fundamental design (such as Alt. 2) will imply significant specification changes, overwhelming implementation and testing efforts.
* Bullet 4: One CORESET#0, one initial BWP, and TDM’ed SSBs in one cell are fundamental designs of NR. Deviating from these fundamental designs will imply significant specification changes, overwhelming implementation and testing efforts.
* Bullet 5: This is a further detail from bullets 2-4. No need to discuss this at this moment.
* Bullet 6: The concept of beam-specific needs to be discussed first before discussing other aspects such as this bullet.
* Bullet 7: Increasing # of SSBs has significant implications, also affecting RAN4 very much. We don’t see this is needed. If larger cell size is needed, satellites could generate larger beams.

Regarding Proposal #4-2:* Bullet 1: It is worth clarifying the scope at an early stage of WI.
* Bullet 2: This could be discussed together with Proposal #4-4.
* Bullet 3: RAN1 could acknowledge the benefits of this and leave the details to RAN2 to decide.
* Bullet 4: It is unclear how this would work considering UE is also moving.

Regarding Proposal #4-3:* Bullet 1: Compared to terrestrial network, the unique aspect of NTN for BM is due to the movement of satellite beams in earth-moving case. And they are predictable and applicable to many UEs in the beam. So, design along the line of the first bullet (measurement-less, group switching) is more reasonable.
* Bullet 2: Measurement on multiple BWPs fundamentally deviates from the existing NR BM design that does not support L1 measurements (beam management or CSI) on non-active BWPs. Design along the line of the second bullet will imply significant specification changes, overwhelming implementation and testing efforts. We suggest not to go in this direction.
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| Sony | Potential proposal #4-1: Partially agree. Agree to discuss the SSB arrangements for beams and BWPs. But the details including various alternatives and enhancements need further discussion. It is better to reuse Rel.15/Rel.16 beam management as much as possible when considering the multiple-beams-per-cell mapping.Potential proposal #4-2: Partially agree. Agree to discuss the TCI indication for beam management in NTN. But the details such as using DCI or MAC CE for beam-specific BWP indication need further discussion. It is better to reuse Rel.15/Rel.16 beam management as much as possible when considering the multiple-beams-per-cell mapping. Whether the TCI activation is based on UE location and satellite ephemeris information or beam reporting from UE is up to gNB implementation. Potential proposal #4-3: Agree. Beam measurement in inactive BWP can be studied. |
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## BWP Configuration, Activation/De-activation

BWP configuration and activation/de-activation can be a mechanism for soft frequency re-use to mitigate inter-beam interference. In NR BWP specifications, BWP#0 can be used for initial and other BWPs can be used for data transmissions. Thales, MediaTek observed that Frequency Reuse schemes are needed to mitigate the inter-cell/inter-beam interference and improve the overall SINR based on system-level simulation for NTN [2, 4].

Huawei [1], MediaTek [4] propose a satellite cell with multiple beams, where several beams can be configured to use a cell-specific BWP common configuration with variable bandwidths depending on traffic load. Huawei further proposed to study extending the number of supported BWPs or introducing a scaling factor to adjust the cell-specific BWP common configuration to enable flexible BWP configuration for NTN.



Qualcomm proposed to consider the following [22]:

* BWP switching schemes to support efficient satellite beam switch.
* Efficient signalling of BWP configurations.
* Enhancements on the beam measurement and reporting to support efficient switching between satellite beams using different frequency.
* Synch raster design to reduce initial access time
* Designing different SIBs based on the system information updating rate

CATT observed the following enhancements to make BWP based beam switching robust in NTN scenarios could be considered [7]:

* DL BWP and UL BWP should be switched together.
* DL synchronization and UL synchronization should be re-estabilished if different beams correspond to different RF branchs of a satellite.
* UE should inform the gNB about the BWP switching completion via UL signal transmission.
* Network should trigger the UE to do BWP switching dedicatedly for beam switching only.

**Potential proposal #4-4: Discuss scope of studies and potential enhancements of BWP configuration and activation/de-activation in NTN:**

* ***BWP switching schemes to support efficient satellite beam switch.***
* ***Efficient signalling of BWP configurations.***
* ***Enhancements on the beam measurement and reporting to support efficient switching between satellite beams using different frequency.***
* ***Synch raster design to reduce initial access time***
* ***Designing different SIBs based on the system information updating rate***
* ***DL BWP and UL BWP pairing for BWP switching***
* ***UE indication of BWP switching completion***
* ***Network triggering mechanisms for BWP switching***

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| **Company** | **Comments and Views on BWP configuration, activation/de-activation** |
| Panasonic | Enhancement for BWP configuration might not be essential. Further study would be needed.  |
| Ericsson | There are many bullets under this proposal, and the details are missing. It is a bit difficult to comment.Our general comment is that BWP configuration and activation/de-activation are supported by existing NR specification already. It is important to ensure NR NTN features to have synergies with NR terrestrial solutions as much as possible. Diverging from terrestrial features would much reduce the chance of NR based NTN being developed. |
| Sony | Can be discussed together with potential proposal #4-2 as beams and BWPs are associated. It is better to reuse Rel.15/Rel.16 BWP switching mechanism as much as possible when considering the multiple-beams-per-cell mapping. |
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## Signalling of Polarization

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 misunderstanding which could result in polarisation loss of several dBs.

Thales further observed that spatial Frequency reuse schemes reduce significantly the inter-beam Co-channel interference but limit the per-beam bandwidth and the system capacity. 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. Circular polarization can be used to double the cell capacity [2]. LG observed Polarization signaling is beneficial for increasing spectral efficiency [15].

Huawei mentioned that for cell measurement, a UE may only turn on the corresponding port according to the polarization state that a target cell employs [1].

Several companies discussed signalling mechanisms for polarisation:

* Ericsson, Huawei proposed NR NTN should support configuration of DL and UL transmit polarization including Right hand and left hand circular polarizations (RHCP, LHCP) [17, 1]
* Ericsson proposed network broadcast DL and UL transmit polarizations used in NR NTN [17]
* Ericsson, ZTE propose UE report its polarization capability to the network [17, 10]
* ZTE propose resource reuse mode with/without polarization should be supported for the beam management enhancement [10]
* Panasonic propose to support operation with fixed polarization per cell/beam for polarization reuse and circular polarisation with intra-UE and inter-UE multiplexing (intra-UE and inter-UE) signalling [14].



***Potential Proposal #4-5: Discuss and study potential enhancements for support of polarisation signalling in NTN:***

* ***Configuration of DL and UL transmit polarization including Right hand and left hand circular polarizations (RHCP, LHCP) [17, 1]***
* ***Network broadcast DL and UL transmit polarizations used in NR NTN [17]***
* ***UE report its polarization capability to the network [17, 10]***
* ***Resource reuse mode with/without polarization for the beam management enhancement [10]***
* ***Fixed polarization per cell/beam for polarization reuse and circular polarisation with intra-UE and inter-UE multiplexing (intra-UE and inter-UE) signalling***

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| **Company** | **Comments and Views on Signalling of Polarisation** |
| Panasonic | Support potential proposal#4-5.  |
| Ericsson | Support.Besides the benefits summarized by Feature Lead, use of polarization is also beneficial for supporting co-existence in frequency bands. This is a highly relevant aspect due to the many plans to deploy mega NGSO constellations in shared Ka-, Ku- and V-bands. High profile constellations such as the one provided by Starlink will e.g. make use of the same spectrum. Not only is the spectrum sharing important between these NGSO constellations, but it is also required between them and existing GEO deployments. ITU Recommendation ITU-R S.1431 provides methods to enhance sharing between NGSO FSS systems and e.g. points out that two systems can share the same spectrum over the same geographical region by means of using different polarizations. Supporting such cases is important for NR NTN to be an attractive alternative for NGSO operators. |
| Sony  | Support potential proposal#4-5. We think all the bullet points under proposal #4-5 are relevant. Additionally, regarding the UE multiplexing and UE polarization capability, reconfigurable polarization for both UL and DL beams can also be studied. Beam management procedure (e.g., SSB transmission) may also be impacted by the polarization capability of devices. |
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# Air To Ground Networks

Air-to-ground (ATG) network refers to in-flight connectivity technique, using ground-based cell towers that send signals up to an aircraft’s antenna(s) of onboard ATG terminal. As a plane travels into different sections of airspace, the onboard ATG terminal automatically connects to the cell with strongest received signal power, just as a mobile phone does on the ground. ATG gNB deployed on the ground, with antennas pointing upward to form an aerial cell, while aircraft performs as a special UE. ATG air interface connects ATG gNB and aircraft, while Wi-Fi connects aircraft and passengers.

There are several regional commercial or trial in-flight networks based on hybrid techniques of ATG and satellite communication, such as Gogo’s commercial network in USA, Inmarsat’s commercial network in Europe, and CMCC’s trial network in China. Regarding the hybrid network, satellite link focus on providing every-where connectivity (e.g., when cross the sea), while ATG link focus on providing high-quality data services for all service available areas (e.g., inland and coastline area).

3 main aspects are for discussion assuming NR TDD deployment at 4.8GHz operating band by CMCC [13]

1. Extreme large cell coverage range (e.g., up to 300 km) and high speed (e.g., up to 1200km/h)
2. Coexistence between ATG and terrestrial network
3. TDD UL-DL Config. with >16 DL slots (e.g., 27DL:4GP:9UL frame structure with 30kHz SCS )

Aspect 1 & 2 are essential, since

- without enhancement for aspect 1, UE may cannot properly access to ATG cell, and

- without enhancement for aspect 2, the performance of terrestrial network may be seriously degraded due to mutual interference from ATG network.

Aspect 3 seems not essential, since if enhancements not supported, 10ms TDD switching period with 12DL:4S:4UL TDD configuration can be utilized instead for deploying ATG network.



CMCC discussed ATG in NR TDD in 5 GHz and makes several proposals to support ATG scenario [13]

1. W.r.t. autonomous acquisition of the TA at UE, broadcasting of the [coarse] location of gNB or gateway via system information
	1. FFS. maximum [x m] random error between accurate position and broadcasted position.
2. W.r.t. autonomous acquisition of the TA at UE, full TA based pre-compensation at UE side is preferred to accommodate to TDD duplex mode.
3. Common TA indication-based solution with pre-compensation at UE side.
4. UL frequency compensation can be realized via network implementation-based solution.
5. Solutions for mitigation of ATG interference to terrestrial network (including terrestrial gNB and UE):
	1. Alt 1: Geography isolating t ATG gNB from terrestrial network.
	2. Alt 2: UL power control with parameter $P\_{CMAX,f,c}\left(i\right)$.
6. A new ATG WI led by RAN4 could be considered on core specifications of RF and RRM requirements for coexistence between ATG and terrestrial network, including,
	1. Co-existence evaluation for ATG network (e.g. ACLR, ACS)
	2. Study and identify new power class UE/BS category for ATG network
	3. Study and identify RF requirements for ATG UE/BS
	4. Study and identify RRM core requirements
7. Extending the value range of dl-DataToUL-ACK field in PUCCH-Config IE to larger than 15, e.g., 31.
8. Support more than 16 HARQ process number in NTN and keep 4-bit HARQ process number field in DCI or just increase to be 5-bit.
9. The time domain window based synchronous and asynchronous HARQ scheme can be used for greater than 16 HARQ process ID indication.

**Companies are invited to comment on these aspects to determine the scope of studies and needs for potential enhancements.**

|  |  |
| --- | --- |
| **Company** | **Comments and Views** |
| Panasonic | Handling of optimization for ATG (TDD) might need RAN plenary discussion.  |
| CMCC | The contribution [13] is intended to provide necessary background information of ATG scenario, such as deployment scenario and technique challenge, and the proposed enhancements are unified for both GEO/LEO and ATG scenarios.For example, the proposal of “Extending the value range of dl-DataToUL-ACK field in PUCCH-Config IE to larger than 15, e.g., 31.” is not a specific requirement of ATG, actually it is also beneficial for LEO to enable flexibly changing of timing relationship via DCI, which may reduce RRC signaling overhead for frequently updating $K\_{offset}$ to fit rapidly changed RTT.So it is suggested to discuss the detail technique solutions in other agendas, and we think the enhancements for NTN can also applied to ATG scenario and resolve the challenges for ATG. |
|  |  |
|  |  |

# Additional Aspects

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

**Companies are invited to comment on these aspects to determine the scope of studies and needs for potential enhancements.**

## Earth-fixed beam and Earth-moving beams

Thales observed earth-Fixed cell, continuously adjusting the beam direction may introduces additional complexity in the satellite antenna system implementation. Beam steering is implementation dependent and it is already in operation for some satellites constellations. A comparison of earth-fixed Vs earth-moving beams is provided below. The Handover rate and the average signalling overhead on an Earth-fixed cell are much less than on an Earth-moving cell. Using a multi-beams cell to mitigate the higher HO Rate on Earth-moving cell might not be always possible. Using multiple beams per cell with beam management can mitigate the higher HO Rate on Earth-moving cell. However, there is an air interface capacity limit to increasing the cell size and the number of beams per cell, particularly in S-Band. In case of fixed cell, the processing load related to Handovers will be high in shorts periods, while zero at other times. By spreading the handover execution duration, the peak in processing power and potential overload of the PRACH resources of the target satellite could be relaxed [2].



|  |  |  |  |
| --- | --- | --- | --- |
|  | **Earth moving beams** | **Earth fixed beams** | **Comments (Impacts: 0: none,1: low,2: high)** |
| **Handover rate** | **2:**Frequent HOs | **1:**Less frequent HOs | Moving cell: -UEs experience periodical changes in the NR cell leading to an increase number in mobility events.-Larger number HOs during a limited time interval in case of traffic hot-spots.Fixed cell: Peak of HO rate depending on the duration (to be defined) all RRC connected UEs are handed over to a new cell at the new satellite. |
| **HO Signaling overhead** | **2:**Regular | **1:**Bursty(group HO, during satellite switch) | Moving cells suffer from recurrent handovers: In these cells, the signaling overhead due to HOs may range from tens of kbps at the nadir to hundreds of kbps at satellite coverage border.  |
| **User Throughput** | **2:**Recurrent HOs may Impact UE Throughput | **1:**Less Impact on UE Throughput | On moving cells there is an undesirable temporary data interruption gap at every handover. This may impact the end user throughput. |
| **User plane interruption** | **2:**impacting mainly the moving cell; due to frequent HOs | **1:**Only interruption at satellite change | User plane interruption duration is likely similar for both scenarios. But, this is impacting mainly the moving cell; due to recurrent HOs.This may cause a bad user experience in time critical data communication like VoNR (Voice over NR). |
| **Load on the PRACH** | **1:**Regular | **1:**Bursty | This may lead to handover failures and call blocking for new calls initiated at the same time. |
| **Processing load related to handovers** | **1:**Regular | **1:**Bursty | In case of fixed beam: the processing load will be high in shorts periods, while zero at other times. |

Thales observed that the impact of earth-fixed beam is expected to be much smaller than earth-moving beams on NR specifications. MediaTek observed that earth-fixed beams have simpler SSB arrangements and BWP configuration and activation/de-activation which can re-use legacy NR specifications [1, 4].

## PAPR

Thales observed that PAPR requirements of CP-OFDM are comparable to the PAPR requirements with multi-DVB-S2X carriers around 8 dB for 99.9% of the time. PAPR requirements with clipping and filtering of CP-OFDM are comparable to the PAPR requirements single DVB-S2X carrier around 4 dB for 99.9% of the time, with some BLER performance loss based MCS (about 0.5 to 1 dB at 1% BLER). PAPR mitigation techniques are implementation dependent and not specified in 3GPP. Hence, the OFDM/NR PAPR requirement on DL transmission matches the PAPR requirements already met in state-of-the-art satellite payloads [2].

## Power Control

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 [12].

Qualcomm proposed to support autonomous reduction of MCS for PUSCH at least for cases when UE is power limited [22]

* Study the exact triggering condition and indication of the reduced MCSTBA

## Positioning enhancements

Rel-17 NR NTN WI identified RAN2/3 objectives for potential issues associated to the use of the existing Location Services (LCS) application protocols to locate UE in the context of NTN and specify adaptations if any. There are no RAN1 objective. The main issue with positioning enhancements is whether GNSS capability is available in UE to determine

Nokia propose (i) RAN1 discuss GNSS usage applications and whether one or more GNSS capabilities classes are needed for NTN; (ii) the error model used to estimate the GNSS-assisted information accuracy should consider additional sources of inaccuracy when the solution does not depend solely on UE position; (iii) RAN1 discuss the total allowed GNSS inaccuracy for different GNSS assisted use cases and whether the use of GNSS is feasible for certain use cases; (iv) RAN1 discuss which GNSS assistance information is available to the NTN UE; (v) : RAN1 to define at least one GNSS accuracy model in 3D space and with time varying behaviour; (vi) RAN1 to define at least one GNSS accuracy model in 3D space and with time varying behaviour. Nokia invited companies to demonstrate the benefit of GNSS for mobility assistance and physical layer signalling adjustment, when considering achievable GNSS accuracy and update rate. Nokia questioned that the UE is unable to autonomously perform TA and Doppler adjustment using its GNSS-based location, because it cannot map the observed PCI to a satellite location [16].

ZTE proposed clarification on the use case and motivation on WI scope w.r.t positioning is needed to identify the potential RAN1 impacts [10].

## CSI enhancements

CSI enhancements to mitigate CSI feedback latency discussed during the study item phase included predication based CSI or averaging based CSI enhancement is discussed during the study item phase. LG observed that both methods can be done by implementation at UE side and/or gNB side with no significant specification impact. In case HARQ feedback is disabled, gNB may rely on the RLC feedback with potentially additional delay. Enhancements could be considered for gNB to set MCS based on bitmap PDSCH detection performance report [15].

## Reference time information

Asia Pacific Telecom propose timestamp method using reference time information broadcast on SIB9 with synchronous receiver GNSS clock in UE to achieve UL synchronization [20]



***Reference time information for UL synchronization will be discussed in UL synchronization AI 8.4.2***

## SLS Parameters

Nomor analyses the list of simulation study cases, used during the Study Item phase and tries to reduce the large set for system level simulations (SLS) during the Work Item phase [3]. Scenarios and need for throughput simulations with frequency re-use factors during the Work Item phase were discussed.

## Companies views on Additional Aspects

Companies are invited to comment on Additional aspects.

|  |  |
| --- | --- |
| **Company** | **Comments and Views additional aspects of Section 6** |
| Panasonic | Regarding 6.1, both Earth-fixed beam and Earth-moving beams are supported in WID, and this impact on other WGs. If this need to be changed, RAN plenary discussion would be needed. Regarding 6.7, we don’t see the necessity of changing the SLS parameters which was intensively discussed and agreed during study item.  |
| Ericsson | * 6.1: Support that RAN1 should focus on earth fixed beam first.
* 6.2: Already concluded in Rel-16 that PAPR discussion is not necessary.
* 6.3: Based on discussion in Rel-16, it appears that the general view is that power control enhancement is not needed.
* 6.4: There is no need to discuss positioning enhancement in RAN1 as RAN1 is not tasked to look into this.
* 6.5: Based on discussion in Rel-16, it appears that the general view is that CSI enhancement is not needed.
* 6.6: To be discussed under 8.4.2.
* 6.7: Not needed for general WI progress.
 |
|  |  |
|  |  |

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# Appendix: Proposals in the RAN1#102e AI 8.2.4 TDocs

## Proposals on Random Access

|  |  |
| --- | --- |
| **Source** | **Related Proposals & Observations** |
| Ericsson | * Proposal 1: RAN1 to identify scenarios where GNSS-equipped UEs cannot perform timing and frequency pre-compensation for uplink synchronization.
* Observation 1: NR NTN features (including PRACH) should have synergies with NR terrestrial solutions as much as possible to help NTN benefit from economies of scale.
* Proposal 2: RAN1 to limit the potential normative work of enhanced PRACH for NTN to the most promising option to minimize the efforts from specification and testing to NW/UE implementations.
* Proposal 3: RAN1 not to deviate from Zadoff-Chu sequences in enhancing PRACH for NTN.
* Observation 2: Simulation results show that the proposed PRACH design using two ZC sequences with an existing root and a complex-conjugate root, can provide satisfactory PARCH detection performance with sufficient time/frequency estimation accuracy for uplink synchronization, in case GNSS-equipped UEs cannot perform the pre-compensation task.
 |
| Huawei | * Proposal 1: There is no need to enhance the preamble design unless the UL frequency and timing error estimated based on UE location and satellite position/velocity exceeds the tolerance of the existing NR preambles.
 |
| ZTE | * Proposal 5: The Option-3 and Option-4 may not be suitable in PRACH enhancement.
* Proposal 6: The Option-1 and Option-2 are suitable for PRACH enhancement.
* Proposal 7: The design of the roots pairs for Option-2 should be further investigated.
* Proposal 8: Enhancement on the PRACH formation to improve the link budget can be considered.
 |
| Intel | * Observation 1: Support for UEs without pre-compensation of timing and frequency offset capabilities is not desirable from system performance perspective
* Proposal 1: UEs without pre-compensation of time and frequency offset capabilities are not considered for the NTN WI
 |
| MediaTek | * Observation 7: With assumption of GNSS capability, UE pre-compensation of delay and Doppler is sufficient for NR NTN scenarios with outdoors UE where GPS receiver can be used.
* Observation 8: Indoor UEs may not receive GNSS signals, but equally may not receive NR NTN signals due to a poorer link budget on DL and UL including wall penetration loss.
* Observation 9: With assumption of GNSS capability, UE pre-compensation of delay and Doppler is sufficient for NR ATG scenarios with ATG UE using aircraft GPS receiver.
* Observation 10: Whether a scenario of direct ATG access with normal NR UE without reliable GPS reception in the aircraft cabin is seen as beneficial should be discussed first before considering a new RACH preamble design.
* Observation 11: Option 2 for new PRACH preamble design based on multiple Zadoff-Chu sequences with different roots has best compromise for implementation complexity, PAPR and CM performance, and impact on legacy specification.
 |
| Panasonic | * Proposal 3: Enhancement on the PRACH sequence and/or format is not considered in Rel.17.
 |
| LG | * Proposal 1. 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.
 |
| Intel | * Support for UEs without pre-compensation of timing and frequency offset capabilities is not desirable from system performance perspective
* UEs without pre-compensation of time and frequency offset capabilities are not considered for the NTN WI
 |
| CMCC |  |
| Fraunhofer | * Observation 1: New ZC sequence lengths, introduced in Release 16, are suitable candidates for employment in NTN, given that they can support all numerologies. The use of new sequences will increase the root sequence reuse factor.
* Proposal 1: RAN1 to consider formats B1, B2, B3, and B4 without CP and with increased number of repetitions for NTN.
* Observation 2: Targeted MDR can be achieved with option-1 of the PRACH enhancements for NTN.
 |

## Proposals on Feeder Link Switching

|  |  |
| --- | --- |
| **Source** | **Related Proposals & Observations** |
| Ericsson | * Observation 3: For a soft feeder link switch scenario, there are no major RAN1 issues for the solution identified in TR 38.821.
* Observation 4: Satellites typically have the capability to connect to multiple gateways by using multiple antennas.
* Observation 5: For feeder link switch, the validness of the scenario where the same gNB is connected to multiple satellite gateways is questionable. In contrast, the feeder link switch involving different gNB’s before and after the switch is more typical.
* Proposal 4: It is up to RAN2 to discuss if the “hard feeder link switch” scenario, where the satellite can only support one feeder link at a time, should be considered in Rel-17.
* Proposal 5: It is up to RAN2 to discuss if the feeder link switch involving same gNB before and after the switch should be considered in Rel-17.
 |
| Huawei | * Proposal 2: Prioritize a subset of representative NTN scenarios for feeder link switch study.
 |
| Nokia | * Observation 3: A feeder link switch for a transparent satellite may result in a cell switch.
* Observation 4: A gNB may switch links of the Uu interface from one satellite and feeder link to another satellite and feeder link, originating from the same NTN-GW.
* Observation 5: An NTN UE may be informed about imminent switch events including the resulting transmission gap.
* Proposal 3: RAN1 to define an assumption of the maximum tolerable gNB – NTN-GW delay.
* Proposal 4: RAN1 to clarify impact of feeder link switch and benefit of signalling assistance information for imminent switch events.
* Proposal 5: RAN1 to define an assumption on the maximum feeder link delay.
 |
| Samsung | * Proposal 1: Mechanism to recover link reliability should be studied in NTN. The use of more robust MCS table can be studied for this purpose.
* Proposal 2: Mechanism to simplify the DCI format should be studied in NTN.
 |
| Intel |  |
| MediaTek | * Proposal 3: Options for mitigation of Doppler over feeder link are for further study
	+ Feeder link Doppler compensation error requirement
	+ GW post compensation of feeder link Doppler
* Proposal 4: Options for mitigation of Delay drift over feeder link are for further study
	+ Feeder link delay drift compensation error requirement
	+ GW compensation of feeder link delay drift
	+ gNB indication of feeder link delay drift
* Proposal 5: Options for feeder link delay for timing relationships and UL synchronization should first be discussed before aspects of feeder link switching are considered.
 |
| CATT | * Proposal 4: In order to support hard 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, UL TA offset, Doppler pre-compensation information of new gateway.
	+ PRACH parameters configuration need to be extended to support massive user handover, including ssb-perRACH-Occasion, Msg1-FDM, PRACH Mask index.
 |
| CMCC |  |
| Interdigital | * Observation 1: 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.
* Observation 2: 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.
* Observation 3: 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.
* Observation 4: Soft feeder link switch has less impact to current specification.
* Proposal 1: Rel-17 supports soft feeder link switch for transparent LEO NTN.
 |

## Proposals on Beam Management, BWP, Signalling on Polarisation

|  |  |
| --- | --- |
| **Source** | **Related Proposals & Observations** |
| Thales | * Observation 18 For loaded cells, Frequency Reuse schemes are needed to mitigate the inter-cell/inter-beam interference and improve the overall SINR
* Observation 19 Spatial Frequency reuse schemes reduce significantly the inter-beam Co-channel interference but inherently limiting the per-beam bandwidth and the system capacity
* Observation 20 Circular polarization can be used to double the cell capacity
* Observation 21 In NTN it might be challenging to implement an optimal and dynamic/fast beamforming towards the users
* Observation 22 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 23 The minimum size of NR beam is the satellite beam’s size
* Observation 24 Beam management can be beneficial in case of multi-beam moving cell
* Observation 25 Deploying multi-beam cell and using beam management will not be applicable to all NTN deployment scenarios
* Observation 26 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
* Observation 27 The size of the common Initial-active BWP should be defined carefully to avoid any congestion and blocking within the cell
* Proposal 4 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
* Proposal 5 NTN should support co-existence of UEs with circularly polarized antennas and linearly polarized antennas on both S-band and Ka-band
* Proposal 6 Focus on single-beam cell (option 1) as baseline without beam management
* Proposal 7 The new beam-specific BWP (BBWP) concept should be introduced on top of existing UE specific BWP
* Proposal 8 The new beam-specific BWP (BBWP) should reuse Release-15/16 BWP operation procedures with the enhancements provided in this TDOC
* Proposal 9 Bandwidth part indicator field on DCI should be unchanged
* Proposal 10 MAC CE transmission configuration indication (MAC CE TCI) can be used to indicate and update serving beam and implicitly the BBW
 |
| Ericsson | * Proposal 6: 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 7: 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 8: The NR network should be able to indicate the timing of the service link switch to UEs in RRC idle and RRC inactive.
* Observation 6: BWP based frequency reuse will negatively impact the supported system capacity.
* Observation 7: Using BWPs to enable a frequency reuse can already be supported by existing NR specification. It is a choice of network configuration and implementation.
* Proposal 9: RAN1 to conclude that there is no need for additional enhancements for using BWPs to enable a frequency reuse.
* Observation 8: NGSO and GSO constellations may make use of shared spectrum e.g. in Ka-, Ku- and V-bands. The requirement on efficient coordination is high, and polarization is an important tool.
* Proposal 10: NR NTN should support configuration of DL and UL transmit polarization including RHCP and LHCP.
* Observation 9: In some cases, a UE cannot be expected to reliably detect the used DL polarization.
* Proposal 11: The gNB should indicate the DL and UL transmit polarizations used in NR NTN using e.g. broadcast signaling.
* Proposal 12: NTN UE should report its polarization capability to the network.
 |
| Huawei | * Proposal 3: BWP configuration enhancement scheme should be studied for NTN.
* Proposal 4: The indication of polarization state for NTN should be supported.
 |
| ZTE | * Proposal 1: Promoting the discussion on beam management with high priority.
* Proposal 2: Resource reuse mode with/without polarization should be supported for the beam management enhancement.
* Proposal 3: Basic assumption on the UE capability w.r.t the polarization should be clarified.
* Proposal 4: Enhancement on the beam management, e.g., measurement-less and group switching, can be considered to improve the performance.
 |
| Qualcomm | * Observation 1: Different options for cell/beam/frequency planning call for flexible standard design.
* Proposal 1: Support both one-beam-per-cell mapping and multiple-beams-per cell mapping.
* Proposal 2: Support satellite beam specific initial BWPs.
* Proposal 3: 3GPP RAN1 to have an agenda item dedicated to SSB arrangements and BWP operation.
* Proposal 4: 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 5: Support broadcasting of beam-specific system information.
* Proposal 6: For the case when SSBs are transmitted in the same frequency interval, down select among the following design options for beam-specific configurations:
	+ Design 1: CORESET#0’s, SIB1’s associated with all satellite beams are in the same frequency interval but initial DL and UL BWPs may not.
	+ Design 2: CORESET#0’s of different satellite beams may have different frequency intervals.
* Proposal 7: Support signalling of the configuration of initial BWPs and CORSET#0 for satellite beams other than the serving satellite beam.
* Proposal 8: Consider BWP switching schemes to support efficient satellite beam switch.
* Proposal 9: Consider efficient signalling of BWP configurations.
* Proposal 10: Consider enhancements on the beam measurement and reporting to support efficient switching between satellite beams using different frequency.
* Proposal 11: Consider synch raster design to reduce initial access time.
* Proposal 12: Consider designing different SIBs based on the system information updating rate.
* Proposal 13: Support autonomous reduction of MCS for PUSCH at least for cases when UE is power limited
	+ Study the exact triggering condition and indication of the reduced MCS
 |
| Samsung | * Proposal 1: Mechanism to recover link reliability should be studied in NTN. The use of more robust MCS table can be studied for this purpose.
* Proposal 2: Mechanism to simplify the DCI format should be studied in NTN.
 |
| Intel | * Optimization of NR beam management design is not necessary for NTN
* Beam management enhancements specified in Rel. 17 in feMIMO WI can be used for NTN
 |
| MediaTek | * Observation 1: Mapping of PCI and SSB to satellite beams/cells option “a” is preferable for earth-moving beams and option “b” is preferable for earth-fixed beams.
* Observation 2: Earth-fixed beam has lower handover signalling requirements and functionality than earth-moving beams.
* Proposal 1: RAN1 discuss prioritization of Earth-fixed beams for GEO and LEO scenarios in Release 17.
* Observation 3: The concept of BWP can be used for frequency resource allocation among NTN beams. Network may configure a specific active BWP for UEs in a beam (all UEs in a beam are associated with the same active BWP). Different beams may be associated with different active BWPs
* Observation 4: A bandwidth part can be used for initial cell access with several beams and corresponding SSBs.
* Observation 5: An active bandwidth part for connected UE can contain one or several beams, where SIB and CSI-RS are transmitted in each beam.
* Observation 6: The DCI or RRC signalling for changing UE’s active BWP configuration may incur a large signalling overhead.
* Proposal 2: In RRC signalling, introduce an association between an SSB index and a BWP index
 |
| OPPO | * Proposal 1: The specification development of the satellite beam layout with FRF > 1 should be prioritized.
* Proposal 2: The relationship between the satellite beam and the BWP operation should be studied and specified.
 |
| Xiaomi | * Proposal 1: One PCI is assumed for a SSB beam set.
* Proposal 2: Solution to trigger both the BWP switch and the beam switch simultaneously need to be supported.
 |
| Lenovo | * Proposal 1: Support option 2 that NZP CSI-RS for beam management is configured in corresponding BWP for different geographical areas/footprints.
* Proposal 2: Consider impact of BWP switching delay for NZP CSI-RS for beam management configured at in corresponding BWPs.
 |
| Sony | * Proposal: Beam management and Bandwidth Parts (BWP) operation for NTN with frequency reuse should be specified.
 |
| Panasonic | * Proposal 1: RAN1 considers to specify a larger number of SSBs allowed for one cell in FR1 for NTN.
* Proposal 2: Schemes to reduce the signaling overhead and UE power consumption for beam management in moving cell scenarios can be considered.
* Proposal 4: Operation with fixed polarization per cell/beam for polarization reuse and operation with intra-UE and inter-UE multiplexing by circular polarization should be supported.
 |
| LG | * Observation 1. Polarization signaling is beneficial for increasing spectral efficiency.
 |
| CATT | * Proposal 1: Support BWP based beam switching enhancement in NTN to reduce beam switching latency.
* Proposal 2: Enable BWP switching of UL and DL simultaneously and support UE confirmation after BWP switching successfully.
* Proposal 3: Allow BWP ID and SSB index jointly to indicate the satellite beam.
 |
| CMCC |  |
| ETRI |  |
| CAICT | * Proposal: Enhance BWP switching used for NTN beam switching to reduce beam switching latency.
 |

## Transparent satellite Aspects, Inter-satellite link, Power Control, PAPR, GNSS/Positioning

|  |  |
| --- | --- |
| **Source** | **Related Proposals & Observations** |
| Thales | Considerations on PAPR requirements for NR NTN downlink transmission:* Observation 1 The PAPR challenges/requirements to be overcome for satellite payload designs based on active antenna are not waveform-specific
* Observation 2 In VHTS payload, it is very common to have several uncorrelated carriers amplified by the same amplifier
* Observation 3 The PAPR requirements of OFDM signals are comparable to the PAPR requirements met with signals composed of several DVB-S2X carriers
* Observation 4 PAPR reduction methods as clipping and filtering can drastically reduce the PAPR requirements of OFDM data signals and make it comparable to the PAPR requirements met with signals composed of single DVB-S2X carrier. However, the resulting performance degradation may become significant depending on the code rate and modulation order
* Observation 5 The evaluation method of PAPR CCDF can diverge depending on the nature of the signals of interest
* Observation 6 The techniques used for achieving the transmitter requirements in terms of unwanted emissions and optimizing the system power efficiency are not specified or mandated in NR specifications

Trade-off Earth fixed cell vs. Earth moving cell:* Observation 7 In Earth-Fixed cell, continuously adjusting the beam direction may introduces additional complexity in the satellite antenna system implementation. Beam steering is implementation dependent and it is already in operation for some satellites constellations
* Observation 8 In Earth-moving cell, UEs experience periodical changes in the NR cell leading to a high Handover rate
* Observation 9 For the UEs located at the cell/beam edge the Dwell\_time will be less and therefore, depending on users distribution within the cell, the HO rate might be much higher
* Observation 10 Moving cells suffer from recurrent handovers: In these cells, the signaling overhead due to HOs may consume a significant part of cell bandwidth
* Observation 11 The Handover rate and the average signalling overhead on an Earth-fixed cell are much less than on an Earth-moving cell
* Observation 12 The air interface capacity is a limiting factor to increasing the cell size and the number of beams per cell. Therefore, using a multi-beams cell to mitigate the higher HO Rate on Earth-moving cell might not be always possible
* Observation 13 The data throughput reduction due to Handovers can be higher in Earth-moving cell while insignificant in Earth-fixed cell
* Observation 14 In case of moving cell deployment where the HO is frequent, the recurrent user plane data transfer interruption may cause a bad user experience in time critical data communication like VoNR (Voice over NR)
* Observation 15 Because of frequent Handovers, and high HO rate in moving cell, there will be a regular processing load related to handovers and regular load on the PRACH
* Observation 16 In case of fixed cell, the processing load related to Handovers will be high in shorts periods, while zero at other times. By spreading the period during which the handover happen, the peak in processing power and potential overload of the PRACH resources of the target satellite could be relaxed
* Observation 17 From RAN perspective, all the specified solutions for Earth-fixed cell will be easily portable to Earth-moving cell
* Proposal 1 Although having multiple beams per cell and using beam management can mitigate the higher HO Rate on Earth-moving cell. This approach should not be considered as baseline. Indeed, there will be always an air interface capacity limit to the number of beams per cell, particularly in S-Band
* Proposal 2 Use mobility enhancements features in NTN (DAPS Handover, Synchronized RA-less handover, and DC-based cell change). These can be beneficial for both moving cell and fixed cell deployment
* Proposal 3 RAN1 to discuss first Earth-fixed cell for GEO and LEO scenarios in Release 17
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| Nokia | Transparent satellite* Observation 1: It is beneficial for the 5G system / gNB to be aware of the transparent satellite’s (time-varying) gain factors.
* Observation 2: The gNB location relative to the NTN-GW may impact the NTN user experience.
* Proposal 1: RAN1 to define the feeder and service link type of amplification of a transparent satellite and potential limitations.
* Proposal 2: RAN1 to clarify that the satellite does not terminate the Uu interface, which implies no manipulation of information context is performed.

Inter satellite link* Proposal 6: RAN1 to define the maximum additional NR-Uu delay due to use of ISL and potential path gain impacts.

GNSS/Positioning* Observation 8: Different use cases may require different accuracy in the use of GNSS-assisted information.
* Observation 6: GNSS can be applied in NTN for country identification, mobility assistance, and physical layer signalling adjustment, but with increasing device cost and power consumption.
* Observation 7: Some GNSS assisted solutions may depend solely on the UE position information (e.g. country identification), whereas others depend on other source of information (e.g. satellite ephemeris for time synchronization).
* Observation 9: There are several sources of inaccuracy for estimating the time/frequency synchronization between UE and gNb by using GNSS location: lag of the ephemeris information, precision of the ephemeris data, GNSS inaccuracy, orbit perturbations and altitude modelling.
* Observation 10: The precision and lag of the ephemeris data and orbits perturbation may have double effect in transparent scenarios.
* Observation 11: the UE is unable to autonomously perform TA and Doppler adjustment using its GNSS-based location, because it cannot map the observed PCI to a satellite location.
* Proposal 8: The error model used to estimate the GNSS-assisted information accuracy should consider additional sources of inaccuracy when the solution does not depend solely on UE position.
* Proposal 9: RAN1 to discuss the total allowed GNSS inaccuracy for different GNSS assisted use cases. And wether the use of GNSS is feasible for certain use cases.
* Proposal 10: RAN1 to discuss which GNSS assistance information is available to the NTN UE.
* Proposal 11: RAN1 to define at least one GNSS accuracy model in 3D space and with time varing behaviour.
* Proposal 12: Companies need to demonstrate the benefit of GNSS for mobility assistance and physical layer signalling adjustment, when considering achievable GNSS accuracy and update rate.
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| ZTE | * Proposal 9: Clarification on the use case and motivation on WI scope w.r.t positioning is needed to identify the potential RAN1 impacts.
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| Samsung | * Proposal 1. The attenuation loss due to forest is reflected for evaluations.
* Proposal 2: In 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.
* Proposal 3: Closed loop power control should be supported in NTN and a mechanism to disable closed loop power control should be considered.
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| LG | * Proposal 2. Consider PDSCH decoding results or probability as new CSI contents.
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| CMCC | ***Proposal 1:*** W.r.t. autonomous acquisition of the TA at UE, broadcasting of the [coarse] location of gNB or gateway via system information is suggested to support ATG scenario.* FFS. maximum [x m] random error between accurate position and broadcasted position.

***Proposal 2:*** W.r.t. autonomous acquisition of the TA at UE, full TA based pre-compensation at UE side is preferred to accommodate to TDD duplex mode in ATG scenario.***Proposal 3:*** Common TA indication-based solution with pre-compensation at UE side can be considered in ATG scenario, with the cost of certain restriction on deployment flexibility.***Proposal 4:*** UL frequency compensation can be realized via network implementation-based solution.***Proposal 5:*** In order to keep terrestrial network from seriously interference caused by ATG network, two potential network implementation-based solutions are proposed:* Alt 1: Geography isolating to mitigate mutual interference from ATG gNB to terrestrial network (including terrestrial gNB and UE).
* Alt 2: UL power control with parameter $P\_{CMAX,f,c}\left(i\right)$ determined for mitigating seriously interference from ATG terminal to terrestrial network (including terrestrial gNB and UE).

***Proposal 6***: A new ATG WI led by RAN4 could be considered on core specifications of RF and RRM requirements for coexistence between ATG and terrestrial network, including,* Co-existence evaluation for ATG network (e.g. ACLR, ACS)
* Study and identify new power class UE/BS category for ATG network
* Study and identify RF requirements for ATG UE/BS
* Study and identify RRM core requirements

***Proposal 7:*** Extending the value range of dl-DataToUL-ACK field in PUCCH-Config IE to larger than 15, e.g., 31.***Proposal 8:*** Support more than 16 HARQ process number in NTN and keep 4-bit HARQ process number field in DCI or just increase to be 5-bit.***Proposal 9:*** The time domain window based synchronous and asynchronous HARQ scheme can be used for greater than 16 HARQ process ID indication. |
| Asia Pacific Telecom | * Observation 1: Reference time information is beneficial for propagation delay estimation and compensation.
* Observation 2: Rather than satellite ephemeris information that needs Kbytes, reference time information may only require 99 bits.
* Proposal 1:Reference time information shall be considered in Rel-17 NTN.
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| Nomor | * Observation 1: Considering a LEO-1200 S-Band scenario, a higher UE throughput can be achieved using a 100% RU instead of a 20% RU.
* Observation 2: Considering a LEO-1200 S-Band scenario with 100% RU, the majority of the UEs show a higher throughput for the case with FRF=3 than for the case with FRF=1. Around 17% of the best users have better performance in case of FRF =1
* Observation 3: Considering a LEO-1200 S-Band scenario with 100% RU and a FRF=1, the difference between the worst and best UEs is significant (5%-tile: 0.29Mbit/s and 95%-tile: 1.10Mbit/s, which is a factor of 3.8).
* Proposal 1: Consider 100% RU and FRF=3 as prioritized scenario for SLS in this Work Item for LEO-1200 S-band scenario.
* Proposal 2: Consider following study cases for system level simulations during the Work Item.
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