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Discussion on NR NTN for Rel-19

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Overview

- Rel-19 NR NTN WID identifies 5 objectives
- For 3 of 5, WID modification based on RAN1 discussion so far is necessary in this RAN plenary meeting
- This document includes discussion on these 3 objectives

1. Study and specify if beneficial downlink coverage enhancements targeting support for additional reference satellite payload parameters covering both GSO and NGSO constellations operating in FR1-NTN or FR2-NTN [RAN1, RAN2, RAN4]
   - Define additional reference satellite payload parameters assuming power sharing among satellite beams or different satellite beam patterns/size (i.e. wide or narrow) across the satellite footprint, such that satellite beams may not all be simultaneously active or may be active below the nominal EIRP density per satellite beam (see section 6.1.1 in TR 38.821) due to limited power and limited feeder link bandwidth.
   - Define the corresponding power sharing assumptions and necessary link level and system level evaluation methodology and relevant KPIs for evaluations of the coverage, to allow for identification of physical channels/signals and system-level aspects that need enhancements and the corresponding needed improvements.
   - **Study and if needed specify solutions, including link level enhancements for FR1-NTN (e.g. for PDCCH, PDSCH) and/or system level enhancements for FR1-NTN and/or FR2-NTN, allowing dynamic and flexible power sharing between satellite beams or different satellite beam patterns/size (i.e. wide or narrow) across the satellite footprint.**
   - Notes for this objective:
     - **SSB channel enhancement is not considered**
     - Antenna gain of UE shall be assumed to be -5.5dBi in case of smartphone in FR1-NTN, the UE is assumed to be a full duplex UE, and at least 2Rx are considered at the UE
     - NGSO to be considered in priority: LEO Set-1 @ 600 km
     - Rel-18 network energy saving techniques should be considered as baseline in the system level study

2. Uplink Capacity/Throughput Enhancement for FR1-NTN [RAN1, RAN2, RAN4]
   - **Study** then specify, **if beneficial, DFT-s-OFDM PUSCH enhancements via Orthogonal Cover Codes (OCC)**
     - **Determine the achievable capacity improvement to be targeted taking into account realistic impairments (e.g. Doppler, time variation, phase distortion, etc)**
     - Specify necessary signalling, if needed
     - Update RF requirements accordingly, if needed
     - Note: The study can consider orthogonal cover codes across OFDM symbols, across slots, and/or within an OFDM symbol.
     - **Note: the study phase is targeted to be completed by RAN#104**
   - Notes for this objective:
     - The enhancement is not targeting improvements/impacts of MU-MIMO capability
     - The enhancement is not targeted to PUSCH DMRS
     - No enhancement for initial access
     - Enhancements to PRACH are not in scope.
     - This feature may be applicable for UEs operating in terrestrial networks based on a common design

3. Specify signaling of the intended service area of a broadcast service (e.g. MBS broadcast) via NR NTN [RAN2, RAN3]
   - Specify SIB signaling to indicate the intended service area in case the satellite footprint covers a larger area. [RAN2]
   - Specify the necessary signaling between CN and NG-RAN. [RAN3]

4. Support of regenerative payload [RAN3, RAN2, RAN4]
   - Specify the support of gNB on board in TS 38.300
   - Specify, if needed, any necessary enhancements related to the intra and inter-gNB mobility, especially for Xn interface over feeder link or over ISL. [RAN3]
   - Note: if any additional necessary stage-3 specifications impact for e.g. NGAP is identified, RAN3 will handle it.

5. Support of Rel-17 RedCap and Rel-18 eRedCap UEs with NR NTN operating in FR1-NTN bands [RAN4, RAN1]
   - For full-duplex FDD RedCap and eRedCap UEs, define the RF and RRM requirements [RAN4]
     - Depending on feasibility assessment ab**For HD-FDD RedCap UEs and eRedCap UEs, check whether any essential changes are needed for their support (i.e. focusing on HD collision rules) by end of Q2/2024 [RAN1]**
     - ove, define the RF and RRM requirements [RAN4]
   - Notes for this objective:
     - GNSS (Global Navigation Satellite Systems) capabilities and simultaneous GNSS and NR-NTN operation is supported in RedCap/eRedCap UE.

DL coverage enhancement

- RAN1 discussion status
  - For link-level study, coverage gaps were identified for several channels in Set 1-3
  - For system-level study, it was argued by several companies that SSB periodicity extension is included in the WI scope (i.e., not covered in 'SSB channel enhancement is not considered'). Meanwhile, it was not common understanding and thereby any clear agreement/conclusion could not be made
- Observation
  - Channels for link-level enhancement can be described in the WID
    - » PDCCH; Msg4 PDSCH; SIB1 PDSCH; SIB19 PDSCH; 1Mbps PDSCH
    - » One important aspect is that enhancement for SIB1/SIB19 should be applicable to other SIBs. There are important SIBs other than SIB1/SIB19 in NTN, e.g., SIB6/SIB7 (ETWS), SIB25 (NTN-specific mobility). When the same enhancement can be applied commonly, there is no need to consider unnecessary restriction
  - Clear guidance on whether SSB periodicity extension is included or not must be explicitly described in the WID or chair's note; otherwise, no progress for system-level aspect is expected in WGs
- Proposal
  - In R19 NTN, PDCCH / Msg4 PDSCH / SIB1 PDSCH / SIB19 PDSCH / 1Mbps PDSCH are enhanced for coverage extension
    - » Enhancement for SIB1/SIB19 is supported for other SIBs, if applicable
  - Make a guidance on whether SSB periodicity extension is included or not

Appendix for DL coverage enhancement

RAN1#116

Agreement

For DL coverage study, consider the following additional reference satellite parameters scenarios for LEO600km Set1 in FR1 (i.e., S-band), referred to as Set1-1 FR1, Set1-2 FR1 and Set1-3 FR1:

LEO600km Set1-1 FR1 (i.e., S-band)	
Maximum Bandwidth per beam	5 MHz
SCS	15 kHz
Beam size(Note 1)	50km
Satellite EIRP density /beam (dBW/MHz)	34
Payload Total DL power level (dBW)	31.24
Aggregated EIRP (Total) (dBW)	61.24*
Satellite Tx max Gain	30 dBi
Maximum EIRP per Satellite beam (dBW)	41
Total number of beam footprints* **	1058
**Total number of simultaneously active beams ** **	106
% simultaneously active beams **	10.02 %

***Note: EIRP limit is 61.24 dBm for the reference configuration.**
****Assuming 100 % Resource Block utilization within the same beam at max power. Absolute number of simultaneously active beams is up to 212 (due to limitation of RF)**
***** For a constellation design at 600km with low elevation angle with 30° and selected (i.e Set 1 parameters) beam size**
Note 1: At least this beam size is considered in this scenario, larger beam sizes maybe evaluated and reported by companies

LEO600km Set1-2 FR1 (i.e., S-band)	
Maximum Bandwidth per beam	5 MHz
SCS	15 kHz
Beam size (note 1)	50km
Satellite EIRP density /beam (dBW/MHz)	34
Payload Total DL power level (dBW)	23
Aggregated EIRP (Total) (dBW)	53*
Satellite Tx max Gain	30 dBi
Maximum EIRP per Satellite beam (dBW)	41
Total number of beam footprints	1058
Total number of simultaneously active beams **	16
% simultaneously active beams **	1.5 %

***Note: EIRP limit is 53 dBm for the reference configuration.**
****Absolute number of simultaneously active beams is up to 16 (due to limitation of RF)**
Note 1: At least this beam size is considered in this scenario, larger beam sizes maybe evaluated and reported by companies

LEO600km Set 1-3 FR1 (i.e., S-band)	
Maximum Bandwidth per beam	5 MHz
SCS	15 kHz
Beam size (note 1)	50km
Satellite EIRP density /beam (dBW/MHz)	26
Payload Total DL power level (dBW)	23.24
Aggregated EIRP (Total) (dBW)	53.24*
Satellite Tx max Gain	30 dBi
Maximum EIRP per Satellite beam (dBW)	33
Total number of beam footprints	1058
Total number of simultaneously active beams **	106
% simultaneously active beams **	10.02 %

***Note: EIRP limit is 53.24 dBm for the reference configuration.**
****Absolute number of simultaneously active beams is up to 212 (due to limitation of RF)**
Note 1: At least this beam size is considered in this scenario, larger beam sizes maybe evaluated and reported by companies

Note: RAN1 will aim to identify necessary enhancements for these scenarios in the study phase. At the end of the study phase, RAN1 will further discuss whether the potential enhancements will be specified within Rel-19 framework.

Appendix for DL coverage enhancement

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Observation

Based on LLS results on PDCCH coverage evaluation collected from different sources:

(omitted)

- With parameter LEO600km Set1-3 FR1:
  - 15 sources observed that there is a PDCCH coverage gap of 3.9dB in average compared to CNR of -9.9 dB.

(omitted)

Observation

Based on LLS results on PDSCH Msg4 coverage evaluation collected from different sources:

(omitted)

- With parameter LEO600km Set1-3 FR1:
  - 11 sources observed that there is a coverage gap for PDSCH with Msg4:
    - The coverage gap is around 4.7 dB on average compared to CNR of -9.9 dB
  - 1 source observed that there is no coverage gap for PDSCH with Msg4 with a coverage margin of 0.3 dB compared to CNR of -9.9 dB

(omitted)

Observation

Based on LLS results on PDSCH SIB1 coverage evaluation collected from different sources:

(omitted)

- With parameter LEO600km Set1-3 FR1:
  - 11 sources observed that there is a coverage gap for PDSCH with SIB1 option 1:
    - The coverage gap is around 4.1 dB on average compared to CNR of -9.9 dB
  - 1 source observed that there is no coverage gap for PDSCH with SIB1 option 1:
    - The coverage margin is 3.4 dB compared to CNR of -9.9 dB
  - 10 sources observed that there is a coverage gap for PDSCH with SIB1 option 2:
    - The coverage gap is around 6.5 dB on average compared to CNR of -9.9 dB
- Note: some results assumed SIB1 combination (where SIB1 is repeated within 160 ms) and some results assumed no SIB1 combination

(omitted)

Observation

Based on LLS results on PDSCH SIB19 coverage evaluation collected from different sources:

(omitted)

- With parameter LEO600km Set1-3 FR1:
  - 10 sources observed that there is a coverage gap for PDSCH with SIB19:
    - The coverage gap is around 3.5 dB on average compared to CNR of -9.9 dB
- Note: all the results above assumed no SIB19 combination

(omitted)

Observation

Based on LLS results on PDSCH 1Mbps coverage evaluation collected from different sources:

(omitted)

- With parameter LEO600km Set1-3 FR1:
  - 5 sources observed that, there is a coverage gap for PDSCH with 1Mbps:
    - The coverage gap is around 5.5 dB on average, compared to CNR of -9.9 dB

(omitted)

Observation

Based on the results of DL coverage ratio evaluation at system level collected from 7 sources for all the three LEO600km satellite parameter sets where the beam footprint diameter is 50 km:

- For Set 1-1/1-3, the coverage ratio can be improved from 10% to 100% if the SSB periodicity is increased from 20ms to 80ms and beam hopping is applied
- For Set 1-2, the coverage ratio can be improved from 1.5% to 96.8% if the SSB periodicity is increased from 20ms to 320ms and beam hopping is applied.
- Note: coverage ratio is N2+N3/ total beam footprints
- Note: the baseline assumes no beam hopping. TDM between SIB1 and SIB19 is assumed in those results, following current specs.

Based on the results of DL coverage ratio evaluation at system level collected from 3 sources for a deployment scenario implementing wide beam footprint:

- 1 source reports that with a deployment of wide beam covering 4 narrow (of 50km size) beams, which means Set 1-2 FR1 with additional EIRP reduction of 6dB, using SSB periodicity of 80 ms can provide coverage ratio of 96.8%, and Set 1-1/1-3 FR1 with additional EIRP reduction of 6dB, SSB periodicity of 80 ms can provide coverage of 100%.
- 1 source observed that for Set 1-1, 1-2 and 1-3, the coverage ratio can be improved from 1.5% to 100% using the legacy default SSB periodicity of 20ms during initial access, by choosing a wide beam footprint with beam footprint sizes of 84 km and 56 km respectively.
  - Note: the PDCCH and the PDSCH for SIB19 is assumed to be transmitted within 2 OFDM symbols and 5 MHz bandwidth. the PDSCH for SIB1 is assumed to be transmitted within 3 OFDM symbols and 5 MHz bandwidth. This assumes no SIB1 and SIB19 transmission in N2 beam footprints. This assumes non-aligned SFN timing across different beams.
- 1 source observed, for Set 1-1 with increased beam size, that the legacy SSB periodicity of 20ms during initial access is usable with NTN beam hopping, by choosing a deployment scenario implementing wide beam footprint with beam footprint sizes of 70.7 km and 86.6 km, leading to a total of 529 and 353 beam footprints within the satellite coverage area, respectively, and the coverage ratio is 80% and 90%, respectively, and a ratio of simultaneously active beam footprints to the total number of beam foot prints equal to 20% and 30%.
  - Note: Beam footprint size is increased by increasing only the *adjacent beam spacing* without increasing the 3dB beamwidth.

Note: RAN1 will further investigate the impact of SSB periodicity extension

Note: Any needed clarification “SSB channel enhancement is not considered” in the WID is up to RAN plenary

Note: RAN1 will further investigate the impact of wider beam of SSB and/or other channels on performance (e.g. link budget, capacity...)

UL capacity/throughput enhancement

- RAN1 discussion status
  - At least RAN1 had a conclusion that OCC techniques should be introduced for purpose of UL capacity/throughput enhancement
  - Which OCC technique from inter-slot/inter-symbol/intra-symbol/combinations should be specified preferentially (i.e., down-selection) was discussed from perspectives of BLER/throughput performance and specification impact, but no conclusion was made yet
    - » E.g., a possible down-selection is to prioritize intra-symbol OCC and inter-slot OCC (and potentially the combination), and to deprioritize inter-symbol OCC
- Observation
  - RAN1 can continue discussion on which OCC technique should be introduced and conclude the issue. Down-selection at RAN plenary to reduce WG workload is not preferred since RAN1 is more appropriate place to discuss technical aspects
  - If scope reduction is necessary, RAN plenary should make a checkpoint to complete down-selection at WGs
- Proposal
  - Start normative work to define OCC techniques for DFT-s-OFDM PUSCH
  - Option 1: WGs continue discussion including potential down-selection of OCC techniques without any guidance from RAN plenary
  - Option 2: A checkpoint is made at RAN#105 to conclude down-selection of OCC techniques in WGs

Appendix for UL capacity/throughput enhancement

RAN1#116bis

Agreement

Support OCC for PUSCH in Rel-19 NR NTN:

- At least PUSCH with Type A repetition
  - FFS PUSCH without Type A repetition for intra-symbol and/or inter-symbol cases
- At least code length 2 or 4, FFS code length 8
- FFS: number of RBs
- Potential OCC techniques listed below are for further down-selection:
  - Inter-slot time-domain OCC with PUSCH repetition Type A
  - Inter-symbol(s) time domain OCC
  - Intra-symbol pre-DFT-s OCC (comb-like structure as in PUCCH format 4)
  - Combinations of OCC techniques
- TBoMS for OCC techniques is FFS

Agreement

RAN1 to at least further study the potential specification aspects on OCC techniques:

- TBS calculation / Rate matching
- UCI multiplexing
- RV cycling across repetitions
- Frequency hopping, e.g. intra /inter slot
- OCC indication/configuration
- Power control
- FFS others aspects

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Agreement

For the normative phase, at least one of the OCC techniques will be specified:

- Inter-slot time-domain OCC with PUSCH repetition Type A with OCC length 2 or 4
- Inter-symbol(s) time domain OCC with OCC length 2 or 4
- Intra-symbol pre-DFT-s OCC (comb-like structure as in PUCCH format 4) with OCC length 2 or 4
- FFS Combination of OCC techniques including multiplexing of 8 UEs
- FFS Use of OCC techniques with TBoMS
- FFS Backward compatibility with non-Rel-19 UEs

Conclusion

OCC with PUSCH can support at least multiplexing of 2 or 4 UEs and achieve up to 2 or 4 times capacity gains respectively, when repetitions are used.

Note: the actual gain may be less due to e.g. intra/inter cell interference.

Support of RedCap/eRedCap UEs in FR1-NTN

- RAN1 discussion status
  - RAN1 identified that TA value assumed at gNB based on TA report may not be aligned with actual TA used at the UE, and this issue does/may lead to performance degradation due to DL/UL overlap handling or due to avoidance of DL/UL overlap
  - There are two directions for this issue, but no clear recommendation of what kind of enhancement should be introduced was made
    - » Direction 1: Enhancement to avoid efficiently DL/UL overlap by gNB scheduler
      - – E.g., TA report enhancement, etc.
    - » Direction 2: New UE behavior when DL/UL overlap of case 3 or case 4 happens
      - – E.g., Overlap handling for cases 3 and 4, Overlap timing indication by UE, etc.
      - – Note: Solution is applicable to cases other than case 3 and case 4
- Observation
  - RAN1 can continue discussion on both directions. Restricting cases or solutions at RAN plenary to reduce WG workload is not preferred since RAN1 is more appropriate place to discuss technical aspects
- Proposal
  - Start normative work to specify UE behavior to mitigate the issues caused by TA mismatch between actual TA used by the UE and assumed TA for the UE at the gNB, at least for cases 3 and 4
  - WGs continue discussion on what kind of enhancement is introduced, without any guidance from RAN plenary

Appendix for support of RedCap/eRedCap UEs in FR1-NTN

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Agreement

Study at least the following scenarios for (e)RedCap HD-FDD UEs for NTN:

- Whether existing handling rules for the following cases should be reused or updated when taking into account TA mismatch between actual TA used by UE and assumed TA at the gNB based on available TA report:
  - Case 1: Dynamically scheduled DL reception collides with semi-statically configured UL transmission
  - Case 2: Semi-statically configured DL reception collides with dynamically scheduled UL transmission
  - Case 3: Semi-statically configured DL reception collides with semi-statically configured UL transmission
  - Case 4: Dynamically scheduled DL reception collides with dynamic scheduled UL transmission
  - Case 5: Configured SSB collides with dynamically scheduled or configured UL transmission
  - Case 6: Dynamic or semi-static DL collides with valid RO
  - Case 7: Collision due to direction switching
- At least the following potential issues can be further considered for (e)RedCap HD-FDD UEs
  - Error cases in case 3 and case 4
  - SIB19 reception collides with UL transmission
  - Slot counting for UL repetition transmission colliding with SSB reception
  - Invalid symbol determination for PUSCH repetition type B
  - Actual TDW determination due to the collision between DL reception and UL transmission with DMRS bundling
  - CPU occupation due to omitted DL reception or UL transmission

Note: Both GSO and Non-GSO should be considered.

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Observation

To avoid the occurrence of error cases 3 and 4 through network scheduling, there are less resources available for a scheduled HD-FDD RedCap/eRedCap UE in NTN compared to TN when there is TA mismatch between actual TA used by the UE and assumed TA for the UE at the gNB.

Observation

For collision cases 1, 2, 5 and 6, when there is TA mismatch between actual TA used by the UE and assumed TA for the UE at the gNB, there might be less resources available for the scheduled HD-FDD RedCap/eRedCap UE in NTN compared to TN if gNB attempts to avoid the collision or there is a loss of DL/UL transmissions due to collision.

Observation

When there is TA mismatch between actual TA used by the UE and assumed TA for the UE at the gNB, there may be a BLER performance degradation for the reception of UL transmissions at the gNB for the scheduled HD-FDD RedCap/eRedCap UE in NTN compared to TN if gNB does not attempt to avoid the collision at least in the following cases:

- UL transmission with repetitions due to different available slot counting at UE and gNB when colliding with SSB reception
- PUSCH repetition type B due to different invalid symbol determination at gNB and UE when colliding with DL transmissions
- UL transmission with DMRS bundling due to the different actual TDW determination at gNB and UE when colliding with DL transmissions

Note: the above cases happen at least with one of collision cases 1, 2, 5, 6, and 7.

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Conclusion

For Rel-19 HD-FDD RedCap/eRedCap UE in NTN, the issues caused by TA mismatch between actual TA used by the UE and assumed TA for the UE at the gNB should be mitigated for collision cases 3 and 4.

- Note: further discussion on other cases is not precluded

Conclusion

For collision cases 1, 2, 5 and 6, the existing priority rules can be reused for a HD-FDD (e)RedCap UE in NTN.

Observation

TA reporting is beneficial to mitigate the TA mismatch between actual TA used by the UE and assumed TA for the UE at the gNB for HD-FDD RedCap/eRedCap UE in NTN from RAN1 perspective.

- Note: complexity, power consumption and signaling overhead impact of TA reporting for (e)redcap UEs was not investigated in this work item

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