**3GPP TSG RAN WG1 #118bis R1-24xxxxx**

**Hefei, China, 14th-18th October 2024**

**Agenda Item : 9.11.4**

**Source : Moderator (Sony)**

**Title :** **FL Summary #1 for IoT-NTN**

**Document for : Discussion and Decision**

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# Introduction

This is the initial FLS for IoT NTN.

**Main Introduction**

This document is the Feature Lead Summary document for the Rel-19 IoT-NTN work item [1].

Items to be considered in this FLS are highlighted with [FL1].

This FLS contains a set of proposals, which can hopefully be addressed in online meeting time at some stage. The document also contains a set of questions. These questions are intended for the purpose of sharing company views. If there is enough agreement, it might be possible to generate proposals.

**NPUSCH**

The following issues are discussed for NPUSCH:

* **OCC schemes to support at 3.75kHz and 15kHz SCS**. Which combination of OCC scheme and DMRS scheme to adopt.
* **3.75kHz single-tone OCC scheme**. Choice between cross-symbol, cross-slot etc.
* **15kHz single tone OCC scheme**. Choice between cross-symbol, cross-slot etc.
* **Multi-tone OCC scheme**. Can this be treated as a second priority?
* **DMRS**. The choice between a CDM or a TDM scheme. The DMRS pattern.
* **UL gaps**. How UL transmission gaps (of various types) affect OCC.
* **Signalling**. Which parameters will need signalling for OCC?
* **Alignment**. Consider how to align OCC between UEs, with gaps and with NPDCCH transmission.

**NPRACH**

Issues related to the following have been identified:

* **Support or not**. Whether NPRACH needs to support OCC.
* **Choice of OCC schemes**. Cross-symbol vs cross-symbol group.
* **NPRACH vs NPUSCH priority**. Whether we should prioritise NPUSCH OCC over NPRACH OCC.
* **RAR impacts**.
* **NPRACH partitioning**. Does NPRACH resource need to be partitioned to support OCC?
* **Signalling**. Which parameters will need signalling for OCC?

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**[FL1] Please consider entering contact info below for the points of contact for this email discussion.**

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# WID objectives

The IoT-NTN WID [1] was updated in RANP#104 and has the following objectives:

|  |
| --- |
| * Support of Capacity enhancements for uplink    + Study then specify, if beneficial, enhancements to enable multiplexing of multiple UEs (e.g. up to the min of 4 and the maximum allowed by the existing UL and DL signalling) in a single 3.75 kHz or 15 kHz subcarrier via orthogonal cover codes (OCC) for NPUSCH format 1 and NPRACH [RAN1, RAN2, RAN4]     - Multi-tone support for 15 kHz SCS should also be considered     - Specify necessary signalling, if needed     - Update RF requirements accordingly, if needed   Note: Impact of impairment shall be taken into account   * + Study and specify, if beneficial the following enhancements to reduce the necessary uplink and downlink signaling to complete an Early Data Transmission (EDT) transaction [RAN2]:     - Msg3 transmission without msg1/ Random Access Response (RAR)     - Efficient delivery (reduced overhead) of msg4 / RRCEarlyDataComplete     - Study and specify RRM requirement, if identified [RAN4] |

# Current and Previous agreements

The following agreements were made in RAN1#116 Athens:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| Agreement#116-IoT-NTN #1  For single-tone NPUSCH format 1 transmissions with both 3.75kHz and 15kHz SCS, the following OCC schemes are considered by RAN1 for further study:   * Time domain OCC where OCC spreads across:   + Symbol-level   + Slot-level   + Repetition-level   + RV-level   For multi-tone NPUSCH format 1 transmissions, the following OCC schemes are considered by RAN1 for further study:   * Time domain OCC where OCC spreads across:   + Symbol-level   + Slot-level   + Repetition-level   + RV-level * Intra-symbol pre-DFT spreading OCC   Agreement#116-IoT-2  The following evaluation assumptions are used for the study of OCC for NPUSCH format 1:   |  |  |  |  |  | | --- | --- | --- | --- | --- | |  | Parameter | value | | | | scenario | orbit | GEO | LEO600 | | | Elevation angle | 12.5 degree | 30degree | | | Channel and impairments | carrier frequency | 2GHz | | | | Channel model | NTN-TDL-C  The channels from different UE are independent. | | | | Frequency error | Uniform random selection from [-0.1 ppm, +0.1 ppm] for all UEs  Variation of frequency error is negligible. | | | | Timing error | Uniform random selection from [-97Ts, +97Ts] for all UEs  Timing drift 80us/s for LEO600 and 0 for GEO. | | | | Power imbalance | **Uniformly distributed between +Pimb and -Pimb for all UEs**  Proponent to report the value of Pimb (can be zero) and justification for the chosen value | | | | transmitter | SCS | 3.75KHz and 15KHz | 15kHz | | | Number of tones | Single tone | Single tone and multi tone up to 12 tones | | | Waveform | DFT-s-OFDM | | | | Frequency hopping | w/o frequency hopping | | | | MIMO scheme | SISO | | | | DMRS configuration | For baseline evaluations:  OS#3 per slot for 3.75kHz  OS#4 per slot for 15kHz  For OCC evaluations:  Up to proponent | | For baseline evaluations:  OS#4 per slot for 15kHz  For OCC evaluations:  Up to proponent | | Number of resource unit () | Up to proponent | | Up to proponent | | Modulation order | Up to proponent | | Up to proponent | | TBS () | Up to proponent | | Up to proponent | | Number of repetitions () | Up to proponent | | | | OCC length | Up to 4 | | | | OCC sequence | Up to proponent | | | | Number of UE | Up to 4 | | | | Velocity of UE | 3km/h | | | | receiver | Receiver algorithm | MMSE | | | | Channel estimation | Real channel estimation | | | | KPI | SNR at 10% BLER | Report for baseline and OCC schemes | | | | Aggregated throughput | Total throughput of up to 4 UEs multiplexed | | | |

The following agreements were made in RAN1#116bis Changsha:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| Agreement  For the NPUSCH evaluation assumptions, update the DMRS configuration, as follows:   |  |  |  | | --- | --- | --- | | DMRS configuration | For baseline evaluations:  OS#4 per slot for 3.75kHz  OS#3 per slot for 15kHz  For OCC evaluations:  Up to proponent | For baseline evaluations:  OS#3 per slot for 15kHz  For OCC evaluations:  Up to proponent |   Agreement  At least the following NPRACH OCC schemes are considered by RAN1 for study:   * Intra-symbol group OCC * Inter-symbol group(s) OCC * Inter-repetition OCC   Agreement  The study of OCC for NPRACH does not consider NPRACH format 2.  Agreement  The following evaluation assumptions are used for the study of OCC for NPRACH:   |  |  |  | | --- | --- | --- | |  | Parameter | value | | Scenario | Orbit and elevation angle | GEO at 12.5 degrees; LEO600 at 30 degrees | | Channel and impairments | carrier frequency | 2GHz | |  | Channel model | NTN-TDL-C  The channels from different UE are independent. | |  | Frequency error | Uniform random selection from [-0.1 ppm, +0.1 ppm] for all UEs  Variation of frequency error is negligible. | |  | Timing error | Uniform random selection from [-97Ts, +97Ts] for all UEs  Timing drift 80us/s for LEO600 and 0 for GEO. | |  | Power imbalance | Uniformly distributed between +Pimb and -Pimb for all UEs  Proponent to report the value of Pimb (can be zero) and justification for the chosen value | | Transmitter | NPRACH format | 1 or 0 | |  | MIMO scheme | SISO | |  | Number of repetitions () | Up to proponent | |  | OCC length | Up to proponent | |  | OCC sequence | Up to proponent | |  | Number of UE | Up to proponent | |  | Velocity of UE | 3km/h | |  | Total NPRACH time / frequency resource utilisation | To be reported by proponent. | | KPI | Target detection probability | 99% | |  | Target false alarm probability | 0.1% | |  | SNR operating point | Report SNR where target detection probability and false alarm probability are reached for baseline and OCC schemes |   Agreement  OCC multiplexing is not supported between a UE using NPUSCH format 1 with 3.75kHz SCS and another UE using NPUSCH format 1 with 15kHz SCS.  Agreement  For OCC of NPUSCH format 1, RAN1 will not consider multiplexing more than 4 UEs.  Agreement  For single-tone DMRS when OCC is applied to NPUSCH format 1, RAN1 considers at least the following for further study:   * TDM of DMRS. The time domain locations of DMRS for different UEs are different. No OCC is applied for the DMRS of different UEs.   + FFS: Detailed mapping * CDM of DMRS. The time domain locations of DMRS for different UEs are the same. Different OCCs are applied for the DMRS of different UEs.   + FFS: Detailed mapping * Other schemes are not precluded, including combinations of the above   Agreement  For the NPUSCH evaluation assumptions, update the frequency error assumption, as follows.   |  |  | | --- | --- | | Frequency error | Uniform random selection from [-0.1 ppm, +0.1 ppm] for all UEs  Variation of frequency error is negligible.  For GEO, the same frequency error is applied to each subframe of a transport block.  For LEO, the same frequency error is applied to each subframe of a segment (if applied in the evaluation). Companies to report their assumption on frequency error across segments. | |

The following agreements were made in RAN1#117 Fukuoka:

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| Agreement  For 3.75kHz single-tone OCC for NPUSCH format 1, RAN1 supports either symbol-level OCC or slot-level OCC. Other OCC schemes are not pursued.  For 15kHz single-tone OCC for NPUSCH format 1, RAN1 supports either symbol-level OCC or slot-level OCC. Other OCC schemes are not pursued.  Agreement  Inter-repetition OCC for NPRACH is not studied further in RAN1.  Agreement   * For the time-domain DMRS pattern (including blanked DMRS, if any):   + For 15kHz single-tone, RAN1 strives to reuse the Rel-17 DMRS pattern   + For 3.75kHz single-tone     - RAN1 studies       * Rel-17 DMRS pattern       * A new DMRS pattern   + The DMRS overhead (including blanked DMRS, if any) for OCC is the same as for Rel-17   Agreement  The Rel-17 guard period locations and length for NB-IoT 3.75kHz UL slot are preserved when OCC is applied to NPUSCH format 1. |

In this meeting (RAN#118 Maastricht), the following agreements were made:

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| Agreement  RAN1 studies whether the following types of UL transmission gap will impact the design of OCC for IoT-NTN when considering e.g. phase continuity   * UL gaps for synchronization (from Rel-13) * Gaps around NPRACH occasions * UL timing adjustment gaps and segmentation for IoT-NTN (from Rel-17) * TDM DMRS that are muted * Guard periods for 3.75kHz UL transmissions   Agreement  The following combinations are considered for further simulation in RAN1 for 3.75kHz SCS OCC for NPUSCH format 1:   * Option 1: OCC2, Symbol-level, TDM DMRS * Option 2: OCC2, Symbol-level, CDM DMRS with new pattern * Option 3: OCC2, Slot-level, TDM DMRS * Option 4: OCC2, Slot-level, CDM DMRS with legacy pattern * Option 6: OCC4, Symbol-level, CDM DMRS with new pattern   The following combinations are considered for further simulation in RAN1 for 15kHz SCS OCC for NPUSCH format 1:   * Option 1: OCC2, Symbol-level, TDM DMRS * Option 3: OCC2, Slot-level, TDM DMRS * Option 4: OCC2, Slot-level, CDM DMRS with legacy pattern * Option 5: OCC4, Symbol-level, TDM DMRS * Option 7: OCC4, Slot -level, TDM DMRS * Option 8: OCC4, Slot-level, CDM DMRS with legacy pattern   Note 1: For TDM, the legacy DMRS pattern, with DMRS symbols appropriately muted/blanked is used. Companies to report their assumption on whether spreading is applied to the legacy DMRS pattern for 15 kHz SCS.  Note 2: Companies to report DMRS sequence applied.  Agreement  For 3.75kHz SCS, NPUSCH format 1 simulations are performed using an appropriate MCS with SNR at least in the range of -8dB to 0dB. |

# NPUSCH

## Overall summary of issues raised in Tdocs

The following is an overall summary of issues raised by companies in input contributions.

**OCC code type**

* Walsh
* DFT [ZTE]
  + Unified design with NR PUCCH format 1

**3.75kHz OCC scheme**

* symbol: QC, LGE, MTK, Nordic
  + High standards and implementation impacts [Apple][CATT][OPPO][ZTE][CMCC]
  + Physical channel mapping rule needs to be changed [LGE][CATT][vivo][CMCC][Spreadtrum] [HW]
    - Without physical channel mapping change, there would be a code rate issue [vivo]
    - Spread first [HW]
  + Better performance [ZTE]
    - Higher tolerance to timing and frequency offset [ZTE]
    - 0.3dB performance loss compared to baseline for OCC2 [CMCC]
  + Symbol level can provide more capacity gain than slot-level up to moderate SNRs using constrained throughput metric [QC]
    - 4x capacity gain with new CDM DMRS pattern
    - 2x capacity gains with TDM pattern
    - Slot-level provides no capacity gains
* Slot: Apple, Sharp, CATT, Interdigital, CMCC, HW
  + Too much phase difference between UEs at maximum frequency offset [QC]
  + Performance is similar to symbol-level
    - Depends on ongoing simulation results [Apple]
    - Via Simulation results [HW]
      * OCC2 performance similar between slot, symbol for TDM DMRS [HW]
    - 1.1dB performance loss compared to baseline for OCC2 [CMCC]
    - Significant performance loss compared to baseline [CATT]
  + Fewer spec impacts [CMCC][OPPO]
  + Physical channel mapping rule needs to be changed [vivo][ZTE][CMCC] [Spreadtrum] [HW]
    - Without a change to the physical channel mapping, there would be an impact on code rate [vivo]
    - Spread first [HW]
  + Better performance [ZTE]
    - Higher tolerance to timing and frequency offset [ZTE]
* Nslot [ZTE][Spreadtrum]
  + Minimum changes to physical channel mapping [ZTE]
  + Performance impacted by frequency and timing offset [ZTE]
* Supported OCC lengths:
  + 2: QC, Apple, Ericsson, MTK, Sharp, HW [sim], CMCC [sim]
  + 4: QC, MTK. Nordic
    - SNR degradation up to 0.5dB [QC]
    - No throughput gain from OCC4 [HW]
    - Further performance evaluation of OCC4 is required [Apple]
    - Downlink signalling will become a bottleneck [Ericsson]
    - New k0 values will be required in DL [Ericsson]
    - Pairing is problematic [Ericsson]
      * How does the scheduler find 4 UEs with similar characteristics that can be OOC-ed together? [Ericsson]
* De-prioritise [Xiaomi][OPPO]
  + Effective multiplexing of users already supported by FDM-ing 4 UEs in 15kHz. No further capacity increase required [Xiaomi]
  + RAN1 discuss whether 3.75kHz OCC is supported or not [OPPO]
    - Error floor in simulations for 3.75kHz SCS [OPPO]
* Prioritise over multi-tone, 15kHz SCS [Interdigital]
  + Natural way to increase capacity is to use 3.75kHz NPUSCH anyway [Interdigital]
* Common design with 15kHz single-tone [Samsung]

Performance of schemes based on 3.75kHz simulations:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Option** |  |  |  | **Loss to baseline** |
| Option 1 | OCC2 | Symbol-level | TDM | HW: 2.31dB  CMCC: 0.3dB  ZTE: 1.0dB  OPPO: 2.5dB (error floor)  QC: 0.29dB |
| Option 2 | OCC2 | Symbol-level | CDM new pattern | HW: 4.84dB  CMCC: 0.1dB  ZTE: -0.1dB  OPPO: 0.2dB (error floor)  QC: 0dB |
| Option 3 | OCC2 | Slot-level | TDM | HW: 2.87dB  CMCC: 1.1dB  ZTE: 1.0dB  Xiaomi: 2.0dB  OPPO: 1.8dB (error floor)  QC: 4.37dB |
| Option 4 | OCC2 | Slot-level | CDM legacy pattern | HW: poor performance  CMCC: 0.7dB  ZTE: 0.1dB  OPPO: poor perf (BLER > 10%)  QC: 3.32dB |
| Option 6 | OCC4 | Symbol-level | CDM new patterm | HW: poor performance  CMCC: 1.1dB  ZTE: 0.2dB  QC: 0.47dB |

**Notes:**

* **loss to baseline (single UE performance) listed for REP8**
* **green text: loss to baseline < 0.5dB**

**15kHz OCC scheme**

* symbol: [Ericsson][Nordic][QC]
  + Symbol level maintains commonality with the 3.75kHz scheme, where slot-level is inapplicable due to the length of the OCC transmission and phase rotation issues [Ericsson]
  + Physical channel mapping spec impact [vivo][ZTE][CMCC] [Spreadtrum] [HW]
    - Without physical channel mapping change, there would be a code rate issue [vivo]
    - Spread first [HW]
  + Better performance [ZTE]
    - Higher tolerance to timing and frequency offset [ZTE]
  + Symbol level can provide more capacity gain than slot-level up to moderate SNRs using constrained throughput metric [QC]
    - 4x capacity gain with CDM DMRS pattern (before OCC)
    - Slot-level with legacy DMRS provides 2x capacity gains [QC]
* slot: [MTK][Sharp][LGE][CATT] [Interdigital][CMCC][Spreadtrum][HW]
  + Simulation results show similar performance to symbol level [OPPO][CMCC][HW]
    - Note: 15kHz SCS has shorter time span than 3.75kHz SCS [CMCC]
    - Similar performance for TDM DMRS [HW][OPPO]
      * symbol better for CDM DMRS [HW]
  + Physical channel mapping spec impact[vivo][ZTE][CMCC][HW]
    - Without physical channel mapping change, there would be a code rate issue [vivo]
    - Spread first [HW]
  + Better performance [ZTE]
    - Higher tolerance to timing and frequency offset [ZTE]
  + Use legacy DMRS pattern [Sharp]
* Nslot [ZTE][Spreadtrum]
  + Minimum changes to physical channel mapping [ZTE]
  + Performance impacted by frequency and timing offset [ZTE]
  + Allows common design with multi-tone [Spreadtrum]
* Supported OCC lengths:
  + 2: Apple, MTK, CATT, HW [sim],CMCC [sim], Nordic
  + 4: QC
    - OCC4 performance is poor from simulation results [CATT]
    - Further performance evaluation of OCC4 is required [Apple]
    - No throughput gain from OCC4 [HW]
* Common design with 3.75 kHz single-tone [Samsung]

Performance of schemes based on 15kHz SCS simulations:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Option** |  |  |  | **Loss to baseline** |
| Option 1 | OCC2 | Symbol-level | TDM | HW: 1.3dB  Vivo: 3.1dB  CMCC: 0.05dB  ZTE: 0.6dB  CATT: 0.7dB  OPPO: 0.8dB |
| Option 3 | OCC2 | Slot-level | TDM | HW: 1.43dB  CMCC: 0.21dB  ZTE: 0.8dB  CATT: 0.2dB  OPPO: 0.8dB |
| Option 4 | OCC2 | Slot-level | CDM legacy | HW: 0.15dB  Vivo: 2.6dB  CMCC: 0.09dB (at REP16)  ZTE: 0.2dB  Xiaomi: 3.5dB  CATT: 0.7dB  OPPO: 0.2dB  QC: 0.37dB |
| Option 5 | OCC4 | Symbol-level | TDM | HW: 3.56dB  CMCC: 4.16dB  ZTE: 3.5dB  CATT: 4.7dB  OPPO: poor performance |
| Option 7 | OCC4 | Slot-level | TDM | HW: 4.44dB  CMCC: 4.86dB  ZTE: 4.4dB  CATT: 4.7dB  OPPO: poor performance |
| Option 8 | OCC4 | Slot-level | CDM legacy | HW: 1.33dB  ZTE: 1.6dB  Xiaomi: 4.7dB  CATT: 4.4dB  OPPO: poor performance  QC: 2.82dB |
|  |  |  |  |  |

**Notes:**

* **loss to baseline (single UE performance) listed for REP8**
* **green text: loss to baseline < 0.5dB**

**Multi-tone support**:

* No: Ericsson
  + Multi-tone would only be applicable in high SNR conditions [Ericsson]
    - High SNR conditions are not an issue since they do not use many resources [Ericsson]
  + Deprioritise multi-tone [Samsung]
    - Only consider if there is time following single-tone discussions [Samsung]
* Yes: Viasat, Lenovo, CMCC, HW, Spreadtrum, Interdigital
  + Newer satellites and HPUE make this viable [Viasat 118]
  + Fast beam hopping favours multi-tone. Good to transmit data before the beam hops [Viasat 118]
* Common time-domain solution with single-tone [Nok][Spreadtrum][Oppo]
  + Different schemes would increase eNB complexity
* Scheme:
  + Symbol [HW]
    - Commonality with single-tone scheme [HW]
  + Nslot [Spreadtrum]
* DMRS
  + Different cyclic shifts [HW]

**Multi-tone OCC scheme**

* slot
  + Minimum specification impact [CATT][CMCC]
  + Unified design with single-tone [CATT]
* Nslot [HW]
  + Performance meets the target [HW]
  + Commonality with single tone scheme [HW]
  + Minimum specification impact [HW]
* Pre-DFT
  + It would be better to do single-tone instead, which already do FDM [ZTE]
* Time-domain approach common to single-tone [Xiaomi]

**Support of both 3.75kHz and 15kHz**

* RAN1#117 agreements mean that both 3.75kHz and 15kHz SCS are supported [Ericsson]

**DMRS multiplexing type**

* CDM: QC, ETRI, ZTE, LGE, NEC
  + Improved channel estimation at 15kHz [CATT]
  + Minimal SNR loss in simulated results for OCC2 [QC][OPPO][ZTE][CMCC]
    - Minimal SNR loss at 15kHz [HW][OPPO]
    - Large SNR loss at 3.75kHz [HW]
  + Loss of orthogonality for DMRS combining due to phase rotation [MTK]
  + Create by spreading DMRS sequence and then applying OCC [QC]
  + Create by masking legacy DMRS sequence with OCC sequence [vivo]
* TDM: HW, ETRI, MTK
  + > 0.2dB loss compared to CDM for symbol-level OCC2 (CFO assumed): QC
  + >1dB loss compared to CDM for OCC4 (CFO assumed): QC
  + 15kHz
    - OCC2: performance loss compared to CDM
      * 1.5dB [HW]
      * 0.8dB [ZTE]
      * 1dB [OPPO]
      * 0.5dB [CATT]
    - OCC4: performance loss compared to CDM
      * 3dB [HW]
      * 2dB [ZTE]
      * 0.3dB [CATT]
  + 3.75kHz
    - OCC2:
      * TDM is 2.7dB better than CDM due to multi-user interference with CDM with CFO [HW]
      * CDM is 0.8dB better than CDM [ZTE]
      * CDM is 2dB better than TDM, but error floor in results [OPPO]
      * CDM is about 0.5dB better than TDM [QC]
  + Performance loss is due to increased combining gain of DMRS with CDM scheme: QC
  + DMRS muting loss [Lenovo]
  + Phase discontinuity between DMRS from a UE [LGE]
    - Due to non-contiguous transmissions
  + Large time gap between consecutive transmitted TDM DMRS leads to performance loss [LGE]
  + Create by masking legacy DMRS sequence with 1/-1/0 pattern [vivo]
  + ON / OFF time mask requires work in RAN4. Without time mask update, there could be distortion [LGE]
  + TDM mapping:
    - UE1 has two consecutive legacy DMRS followed by UE2 [CMCC][HW]
      * Shorter timespan for a UE avoids wrap-around [CMCC][HW]
    - UE1 and UE2 have alternate legacy DMRS
* Multi-tone
  + Cyclic shifts [HW]
    - Existing cyclic shift mechanism can be used [HW]
  + OCC2:
    - TDM [CMCC]
  + OCC4:
    - TDM + FDM (or + comb-like) [CMCC]

**DMRS sequence**

* Update DMRS sequence [vivo][TCL][Nok][LGE]

**3.75kHz DMRS pattern**

A blue squares on a white background

Description automatically generated

* Within cluster separation is x1 symbols, between cluster separation is x2 symbols [QC][NEC]
  + X1 maintains pull-in range, x2 retains DMRS density [QC]
  + X1 should be less than or equal to 8 symbols for CFO / pull-in range reasons [NEC]
  + M consecutive symbols assigned to DMRS; start symbol of a set of DMRS is a multiple of M [QC]
  + Support pattern in the figure above [QC]
  + Slot-level OCC cannot be used as the slots have different structures [HW]
  + For OCC2: [LGE]
    - Slot index mod 2 = 0: DMRS in OS#6
    - Slot index mod 2 = 1: DMRS in OS#0
  + For OCC4: [LGE]
    - Slot index mod 4 = 0: DMRS in OS#5, OS#6
    - Slot index mod 4 = 1: DMRS in OS#0, OS#1
    - Slot index mod 4 = 2 or 3: no DMRS
  + New DMRS scheme will lead to implementation work at eNB [Nok]
* New DMRS pattern is required [QC][Ericsson][NEC][LGE][ETRI]
* Distance between corresponding DMRS must be <= 8 symbols [NEC]
  + Based on CFO = 0.1ppm [NEC]
* Legacy DMRS pattern with different DMRS sequences for different OCC index [Nok]
* Proposal to clarify new DMRS pattern spreading [QC]
  + For 3.75kHz SCS and an OCC order of M, the DMRS pattern is defined as a set of positions within an RU, with the following constraints:
    - M consecutive symbols are allocated to DMRS.
    - The start symbol of a set of DMRS symbols is a multiple of M.

**15kHz DMRS pattern**

* Legacy DMRS pattern used [NEC][LGE][Nok][QC]
  + New pattern will lead to alignment problem between UEs [Nok]
  + New DMRS scheme will lead to implementation work at eNB [Nok]
  + Legacy pattern is legacy pattern before OCC [QC]
* Distance between corresponding DMRS must be <= 35 symbols [NEC]
  + Based on CFO = 0.1ppm [NEC]
* Legacy DMRS pattern with different DMRS sequences for different OCC index [Nok]

**Features that NPUSCH should work with:**

* Connected mode dynamic grant [QC]
* EDT [QC][TCL]
* PUR [QC][TCL]
  + Consider relationship of OCC to “shared PUR” in Rel-16 [Ericsson]
* RACH-less EDT (R19) [QC]
* Compatibility and coexistence between OCC and non-OCC UEs [Nok]

**UL gaps:**

* Need to align OCC around transmission gaps [QC]
* Need to accurately align UEs if their NPUSCH starting times cause gaps to occur at different times [QC]
* Align OCC DMRS such that they don’t straddle a gap [QC]
* Postpone around an UL gap [Ericsson]
* OCC does not span UL NTN segment gaps [LGE][Nok][vivo][Spreadtrum][HW]
  + There is pre-compensation within an UL segment and phase continuity is not maintained between UL segments [LGE][Nok]
  + Drop any OCC codeword that at least partially spans an UL segment gap [Nok]
* Approaches to mitigate gaps in OCC transmissions:
  + OCC sequences that are robust to time misalignment [Ericsson]
  + Timing correction / control functionality at UE transmitter [Ericsson]
  + Receiver processing techniques to compensate for distortion in gaps [Ericsson]
* RAN4 issues
  + Send LS to RAN4 requesting information on stability of UE CFO over time and across gaps [Sony]
    - Currently no CFO stability requirements in RAN4 and these might affect performance of long transmissions or re-transmissions [Sony]
* UL gaps for synchronization (from Rel-13)
  + Drop OCC segment that spans gap [Spreadtrum][vivo]
  + Phase continuity broken across gap [vivo]
  + eNB does not schedule UE with OCC if the NPUSCH would span a gap [vivo]
  + Consider in design / further study [CMCC][CATT][ETRI]
  + OCC is orthogonal both before and after a gap [Apple]
* Gaps around NPRACH occasions
  + Drop OCC segment that spans gap [Spreadtrum]
  + Consider in design / further study [CMCC][CATT]
  + NPRACH and UL gaps require postponements [Ericsson]
  + Align OCC scheme around NPRACH gaps [QC]
* UL timing adjustment gaps and segmentation for IoT-NTN (from Rel-17)
  + Drop OCC segment that spans gap [Spreadtrum][Apple]
  + OCC does not span UL segment gap [vivo]
  + Study how to put gaps and segments in appropriate places to avoid dropping issues [CATT]
  + UL TA gaps are not an issue if segment length is a multiple of OCC length [MTK]
  + Consider in design [CMCC][Apple][ETRI]
* TDM DMRS that are muted
  + No issue [Spreadtrum][vivo][CMCC][CATT]
    - < 13 OFDM symbols (from NR coverage enhancement work), hence phase continuity is maintained [vivo]
* Guard periods for 3.75kHz UL transmissions
  + No issue [Spreadtrum] [CMCC][ETRI]
    - Gap length is very short and not significant phase rotation [Spreadtrum][ETRI]
    - < 13 OFDM symbols (from NR coverage enhancement work), hence phase continuity is maintained [vivo]

**Physical channel mapping**

* Resource unit size
  + Increase RU size
    - Super-RU = M RUs [QC]
    - Avoids a reduction of coding rate [QC]
  + Increase RV size
    - Super-RV = NRU super-RUs [QC]
    - Avoids a reduction of coding rate [QC]
  + Physical channel mapping rules need to change [LGE][QC][OPPO]
    - Cross-symbol
    - Cross slot
      * Increase to be the target OCC length [LGE]
* TBS determination
  + Based on multiplication of slots of allocated RU by OCC length [OPPO]
  + Based on multiplication of symbols in a slot multiplied by OCC length [OPPO]
* Method
  + “pause and repeat across symbol” [OPPO]
    - Note: this is equivalent to “pause and repeat across slot” in current spec [OPPO]

**Signalling**

* Aspects that need to be signalled:
  + OCC factor (M) [QC][ETRI] [Sharp]
  + OCC codeword [QC][Sharp][TCL]
  + OCC feature enabling [QC][Sharp][TCL]
  + Sequence type (DFT or Walsh) [ETRI]
* RRC [ETRI][Spreadtrum]
  + OCC feature enabling [QC][TCL]
  + OCC factor (M) [QC] [ETRI]
* DCI [ETRI][Sharp][Speradtrum]
  + OCC codeword [QC][Sharp][TCL]
  + OCC feature enabling [Sharp]
    - Allows fast switch between OCC scheme and legacy NPUSCH [Sharp]
  + Maintain DCI size [Sharp][TCL]
    - Does not increase blind decoding effort at UE [Sharp]
    - Reinterpretation of DCI fields [Sharp]
      * Reinterpret bits in MCS field [TCL]
* MAC CE
* Implicitly derived

**Pairing**

* RAN1 study potential loss of orthogonality from pairing UEs [Ericsson]
* Factors to be considered for pairing:
  + Traffic characteristics [Ericsson]
  + Number of repetitions [Ericsson]
  + Modulation schemes [Ericsson]
  + Location [Ericsson]
  + Power [Ericsson]
* Can be solved by network for NPUSCH [Spreadtrum]
  + E..g based on CQI in Msg3 [Spreadtrum]

**Downlink issues**

* Increase in NPDCCH resource [Ericsson]
  + 4 OCC NPUSCH requires 4 DCIs [Ericsson]
* Alignment of NPUSCH requires staggered NPDCCH, requiring new k0 values (subframes between NPDCCH and NPUSCH) [Ericsson]
* NPUSCH from different UEs need alignment [Nok]

**Alignment**

* Alignment of NPUSCH requires staggered NPDCCH, requiring new k0 values (subframes between NPDCCH and NPUSCH) [Ericsson]
* Reference point in time introduced to align OCC from different UEs [TCL]
* Alignment of adding new UEs with OCC to existing group of UEs already doing OCC [QC]
* Alignment of codewords around OCC gaps [QC]
* New DMRS schemes will lead to difficulty of alignment of UEs. [Nok]
  + Applies to both TDM and CDM [Nok]

**PAPR**

* eNB PAPR may be increased with PAPR [Ericsson]
  + Consult RAN4

## OCC schemes to support at 3.75kHz SCS and 15kHz SCS

The Qualcomm contribution [R1-2408870] provides results on constrained throughput for a variety of schemes in these figures:

A graph showing the number of data

Description automatically generated with medium confidence

Figure 1 Constrained throughput for different OCC options at 3.75kHz SCS

A graph showing the number of objects in the same direction

Description automatically generated with medium confidence

Figure 2 Constrained throughput for different OCC options at 15kHz SCS

The Ericsson contribution [R1-2408735] provides the following comparison between alternative approaches to supporting OCC schemes at 3.75kHz and 15kHz:

|  |  |  |
| --- | --- | --- |
| **Alternative 1** | **Alternative 2** | **Alternative 3** |
| * OCC for NPUSCH Format 1 single-tone with 3.75 kHz SCS supports a “symbol-level OCC” scheme. * OCC for NPUSCH Format 1 single-tone with 15 kHz SCS supports a “symbol-level OCC” scheme. | * OCC for NPUSCH Format 1 single-tone with 3.75 kHz SCS supports a “slot-level OCC” scheme. * OCC for NPUSCH Format 1 single-tone with 15 kHz SCS supports a “slot-level OCC” scheme. | * OCC for NPUSCH Format 1 single-tone with 3.75 kHz SCS supports a “symbol-level OCC” scheme. * OCC for NPUSCH Format 1 single-tone with 15 kHz SCS supports a “slot-level OCC” scheme. |
| **Comment:** Alternative 1 aims for design commonality, while avoids the potential issue related with the “DMRS phase difference” for NPUSCH Format 1 single-tone with 3.75 kHz SCS.  One drawback that has been highlighted for this alternative is that is foreseen to results in a larger specification impact compared with supporting a “Slot-level OCC” scheme. | **Comment:** Alternative 2 aims for design commonality, while the potential issue related with the “DMRS phase difference” for NPUSCH Format 1 single-tone with 3.75 kHz SCS is claimed to be alleviated through supporting at most up to 2 OCC’d UEs.  One advantage of Alternative 2 is that is foresen to result in less specification impact compared with supporting a “Symbol-level OCC” scheme.  One drawback of Alternative 2 is that the suitability (performance-wise) of using a “Symbol-level OCC” scheme for NPUSCH Format 1 single-tone with 3.75 kHz SCS is still under discussion and depends on reaching a common understanding and acknowledgement of the obtained result. | **Comment:** Alternative 3 assigns the OCC scheme that in principle results to be more suitable in each case. That is, NPUSCH Format 1 single-tone with 15 kHz SCS can afford a slot-level OCC scheme, whereas NPUSCH Format 1 single-tone with 3.75 kHz SCS using symbol-level OCC scheme won’t incurr in any “DMRS phase difference” issue.  One drawback of this alternative is the lack of design commonality. |

The above high level summary leads to the following proposal (also from [R1-2408735]):

[FL1] Proposal 4\_2\_1v1: For the support of OCC for NPUSCH format 1 single-tone, RAN1 performs a down-selection of one of the following alternatives:

Alternative 1:

* OCC for NPUSCH Format 1 single-tone with 3.75 kHz SCS supports a “symbol-level OCC” scheme.
* OCC for NPUSCH Format 1 single-tone with 15 kHz SCS supports a “symbol-level OCC” scheme.

Alternative 2:

* OCC for NPUSCH Format 1 single-tone with 3.75 kHz SCS supports a “slot-level OCC” scheme.
* OCC for NPUSCH Format 1 single-tone with 15 kHz SCS supports a “slot-level OCC” scheme.

Alternative 3:

* OCC for NPUSCH Format 1 single-tone with 3.75 kHz SCS supports a “symbol-level OCC” scheme.
* OCC for NPUSCH Format 1 single-tone with 15 kHz SCS supports a “slot-level OCC” scheme.

FL thinks that this is a good proposal for progressing discussions and comments are invited in the table below:

|  |  |
| --- | --- |
| **Company** | **Comment** |
|  |  |
|  |  |
|  |  |

## 3.75kHz single-tone OCC scheme

The following views were expressed about the type of OCC scheme that should be supported for 3.75kHz single-tone:

* symbol: QC, LGE, MTK, Nordic
  + High standards and implementation impacts [Apple][CATT][OPPO][ZTE][CMCC]
  + Physical channel mapping rule needs to be changed [LGE][CATT][vivo][CMCC][Spreadtrum] [HW]
    - Without physical channel mapping change, there would be a code rate issue [vivo]
    - Spread first [HW]
  + Better performance [ZTE]
    - Higher tolerance to timing and frequency offset [ZTE]
    - 0.3dB performance loss compared to baseline for OCC2 [CMCC]
  + Symbol level can provide more capacity gain than slot-level up to moderate SNRs using constrained throughput metric [QC]
    - 4x capacity gain with new CDM DMRS pattern
    - 2x capacity gains with TDM pattern
    - Slot-level provides no capacity gains
* Slot: Apple, Sharp, CATT, Interdigital, CMCC, HW
  + Too much phase difference between UEs at maximum frequency offset [QC]
  + Performance is similar to symbol-level
    - Depends on ongoing simulation results [Apple]
    - Via Simulation results [HW]
      * OCC2 performance similar between slot, symbol for TDM DMRS [HW]
    - 1.1dB performance loss compared to baseline for OCC2 [CMCC]
    - Significant performance loss compared to baseline [CATT]
  + Fewer spec impacts [CMCC][OPPO]
  + Physical channel mapping rule needs to be changed [vivo][ZTE][CMCC] [Spreadtrum] [HW]
    - Without a change to the physical channel mapping, there would be an impact on code rate [vivo]
    - Spread first [HW]
  + Better performance [ZTE]
    - Higher tolerance to timing and frequency offset [ZTE]
* Nslot [ZTE][Spreadtrum]
  + Minimum changes to physical channel mapping [ZTE]
  + Performance impacted by frequency and timing offset [ZTE]
* Supported OCC lengths:
  + 2: QC, Apple, Ericsson, MTK, Sharp, HW [sim], CMCC [sim]
  + 4: QC, MTK. Nordic
    - SNR degradation up to 0.5dB [QC]
    - No throughput gain from OCC4 [HW]
    - Further performance evaluation of OCC4 is required [Apple]
    - Downlink signalling will become a bottleneck [Ericsson]
    - New k0 values will be required in DL [Ericsson]
    - Pairing is problematic [Ericsson]
      * How does the scheduler find 4 UEs with similar characteristics that can be OOC-ed together? [Ericsson]
* De-prioritise [Xiaomi][OPPO]
  + Effective multiplexing of users already supported by FDM-ing 4 UEs in 15kHz. No further capacity increase required [Xiaomi]
  + RAN1 discuss whether 3.75kHz OCC is supported or not [OPPO]
    - Error floor in simulations for 3.75kHz SCS [OPPO]
* Prioritise over multi-tone, 15kHz SCS [Interdigital]
  + Natural way to increase capacity is to use 3.75kHz NPUSCH anyway [Interdigital]
* Common design with 15kHz single-tone [Samsung]

It is generally accepted that, as a trend, a shorter timespan for the OCC scheme will lead to better performance. This would favour support of the symbol-based scheme over the slot-based scheme. An Nslot-based scheme shows a performance loss according to simulation results from ZTE.

There is general consensus that a cross-symbol based scheme would require changes to the physical channel mapping, but this is also probably required for cross-slot OCC. In particular, a spreading (repetition) operation would be required on the symbols (see Figure 4), where the RU length is multiplied by the OCC factor to take into account the spreading [QC]. The OCC is then applied on the spread symbols. If the RU length is not increased, there will be a reduction in code rate [vivo][QC].



Figure 4 Symbol-level OCC with and *L*=2 (from R1-2407663 – Huawei)

This spreading operation is probably also required for a cross-slot scheme, as illustrated in Figure 5. One way of performing this spreading operation would be to define Nslot = 2 for single slot, thus yielding identical slots over which OCC can be performed



Figure 5 Slot-level OCC with and *L*=2 (from R1-2407663 – Huawei)

A summary of the simulated performance results for the scheme options that were identified in RAN1#118 is provided in Table 1 below:

Table 1 – Summary of simulated performance for 3.75kHz SCS single-tone scheme options

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Option** |  |  |  | **Loss to baseline** |
| Option 1 | OCC2 | Symbol-level | TDM | HW: 2.31dB  CMCC: 0.3dB  ZTE: 1.0dB  OPPO: 2.5dB (error floor)  QC: 0.29dB |
| Option 2 | OCC2 | Symbol-level | CDM new pattern | HW: 4.84dB  CMCC: 0.1dB  ZTE: -0.1dB  OPPO: 0.2dB (error floor)  QC: 0dB |
| Option 3 | OCC2 | Slot-level | TDM | HW: 2.87dB  CMCC: 1.1dB  ZTE: 1.0dB  Xiaomi: 2.0dB  OPPO: 1.8dB (error floor)  QC: 4.37dB |
| Option 4 | OCC2 | Slot-level | CDM legacy pattern | HW: poor performance  CMCC: 0.7dB  ZTE: 0.1dB  OPPO: poor perf (BLER > 10%)  QC: 3.32dB |
| Option 6 | OCC4 | Symbol-level | CDM new patterm | HW: poor performance  CMCC: 1.1dB  ZTE: 0.2dB  QC: 0.47dB |

**Notes:**

* **loss to baseline (single UE performance) listed for REP8**
* **green text: loss to baseline < 0.5dB**

**[FL1] Question 4\_3\_1: From the performance perspective, what conclusion do you draw on the simulated performance for 3.75kHz single-tone OCC schemes?**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| SONY | OCC2: option 2 (symbol level, new DMRS pattern) works by consensus  OCC4: option 6 is feasible  The results from HW are an outlier to these conclusions |
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## 15kHz single-tone OCC scheme

The following views were expressed about the type of OCC scheme that should be supported for 15kHz single-tone:

* symbol: [Ericsson][Nordic][QC]
  + Symbol level maintains commonality with the 3.75kHz scheme, where slot-level is inapplicable due to the length of the OCC transmission and phase rotation issues [Ericsson]
  + Physical channel mapping spec impact [vivo][ZTE][CMCC][HW]
    - Without physical channel mapping change, there would be a code rate issue [vivo]
    - Spread first [HW]
  + Better performance [ZTE]
    - Higher tolerance to timing and frequency offset [ZTE]
  + Symbol level can provide more capacity gain than slot-level up to moderate SNRs using constrained throughput metric [QC]
    - 4x capacity gain with CDM DMRS pattern (before OCC)
    - Slot-level with legacy DMRS provides 2x capacity gains [QC]
* slot: [MTK][Sharp][LGE][CATT] [Interdigital][CMCC][HW]
  + Simulation results show similar performance to symbol level [OPPO][CMCC][HW]
    - Note: 15kHz SCS has shorter time span than 3.75kHz SCS [CMCC]
    - Similar performance for TDM DMRS [HW][OPPO]
      * symbol better for CDM DMRS [HW]
  + Physical channel mapping spec impact[vivo][ZTE][CMCC][HW]
    - Without physical channel mapping change, there would be a code rate issue [vivo]
    - Spread first [HW]
  + Better performance [ZTE]
    - Higher tolerance to timing and frequency offset [ZTE]
  + Use legacy DMRS pattern [Sharp]
* Nslot [ZTE][Spreadtrum]
  + Minimum changes to physical channel mapping [ZTE]
  + Performance impacted by frequency and timing offset [ZTE]
  + Allows common design with multi-tone [Spreadtrum]
* Supported OCC lengths:
  + 2: Apple, MTK, CATT, HW [sim],CMCC [sim], Nordic
  + 4: QC
    - OCC4 performance is poor from simulation results [CATT]
    - Further performance evaluation of OCC4 is required [Apple]
    - No throughput gain from OCC4 [HW]
* Common design with 3.75 kHz single-tone [Samsung]

The timespan of the OCC codewords is lower at 15kHz than at 3.75kHz and hence the OCC operation is expected to be less affected by CFO than at 3.75kHz SCS.

A summary of the simulated performance results for the scheme options that were identified in RAN1#118 is provided in Table 1 below:

Table 1 – Summary of simulated performance for 3.75kHz SCS single-tone scheme options

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Option** |  |  |  | **Loss to baseline** |
| Option 1 | OCC2 | Symbol-level | TDM | HW: 1.3dB  Vivo: 3.1dB  CMCC: 0.05dB  ZTE: 0.6dB  CATT: 0.7dB  OPPO: 0.8dB |
| Option 3 | OCC2 | Slot-level | TDM | HW: 1.43dB  CMCC: 0.21dB  ZTE: 0.8dB  CATT: 0.2dB  OPPO: 0.8dB |
| Option 4 | OCC2 | Slot-level | CDM legacy | HW: 0.15dB  Vivo: 2.6dB  CMCC: 0.09dB (at REP16)  ZTE: 0.2dB  Xiaomi: 3.5dB  CATT: 0.7dB  OPPO: 0.2dB  QC: 0.37dB |
| Option 5 | OCC4 | Symbol-level | TDM | HW: 3.56dB  CMCC: 4.16dB  ZTE: 3.5dB  CATT: 4.7dB  OPPO: poor performance |
| Option 7 | OCC4 | Slot-level | TDM | HW: 4.44dB  CMCC: 4.86dB  ZTE: 4.4dB  CATT: 4.7dB  OPPO: poor performance |
| Option 8 | OCC4 | Slot-level | CDM legacy | HW: 1.33dB  ZTE: 1.6dB  Xiaomi: 4.7dB  CATT: 4.4dB  OPPO: poor performance  QC: 2.82dB |
|  |  |  |  |  |

**Notes:**

* **loss to baseline (single UE performance) listed for REP8**
* **green text: loss to baseline < 0.5dB**

**[FL1] Question 4\_4\_1: From the performance perspective, what conclusion do you draw on the simulated performance for 15kHz single-tone OCC schemes?**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| SONY | OCC2: Option 4 (slot level, legacy CDM) works according to consensus  The results from vivo and Xiaomi are outliers to these conclusions  OCC4: no good scheme identified. Don’t support OCC4 at 15kHz SCS |
|  |  |
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|  |  |

## Multi-tone OCC scheme

The following views were expressed about the type of OCC scheme that should be supported for multi-tone:

**Multi-tone support**:

* No: Ericsson
  + Multi-tone would only be applicable in high SNR conditions [Ericsson]
    - High SNR conditions are not an issue since they do not use many resources [Ericsson]
  + Deprioritise multi-tone [Samsung]
    - Only consider if there is time following single-tone discussions [Samsung]
* Yes: Viasat, Lenovo, CMCC, HW, Spreadtrum, Interdigital
  + Newer satellites and HPUE make this viable [Viasat 118]
  + Fast beam hopping favours multi-tone. Good to transmit data before the beam hops [Viasat 118]
* Common time-domain solution with single-tone [Nok][Spreadtrum][Oppo]
  + Different schemes would increase eNB complexity
* Scheme:
  + Symbol [HW]
    - Commonality with single-tone scheme [HW]
  + Nslot [Spreadtrum]
* DMRS
  + Different cyclic shifts [HW]

**Multi-tone OCC scheme**

* slot
  + Minimum specification impact [CATT][CMCC]
  + Unified design with single-tone [CATT]
* Nslot [HW]
  + Performance meets the target [HW]
  + Commonality with single tone scheme [HW]
  + Minimum specification impact [HW]
* Pre-DFT
  + It would be better to do single-tone instead, which already do FDM [ZTE]
* Time-domain approach common to single-tone [Xiaomi]

If multi-tone were to be supported for OCC, there seems to be consensus that a slot-based or Nslot-based approach would be suitable, from a performance perspective and from the specification impact that the pre-DFT-based approach would entail.

However, there are concerns that multi-tone transmissions aren’t suitable for NTN since they are more suitable high for SNR conditions (that are not really achieved in NTN). In lower SNR conditions, multiplexing more users can be achieved by scheduling single-tone transmissions.

In previous meetings, a lot of time has been spent on choice of the single-tone scheme. This has meant that there has not been time to discuss the multi-tone scheme. There are concerns over whether multi-tone OCC would actually be used, when there is the opportunity to schedule single-tone instead. This would seem to indicate that multi-tone is a lower priority for many companies. There are views expressed that there should be commonality between the single-tone scheme and any multi-tone scheme. This would suggest that it would be beneficial to firstly decide on a single-tone scheme and then consider a multi-tone tone scheme that has maximum commonality with the single-tone scheme.

Hence, it is proposed to prioritise the single-tone scheme over the multi-tone scheme and come back to multi-tone once a single-tone scheme has been decided on.

**[FL1] Proposal 4.5-1: RAN1 prioritises the single-tone OCC schemes. Once single-tone schemes have been agreed, RAN1 can revisit multi-tone, aiming to minimise differences from the single-tone schemes.**

Companies are invited to comment on proposal 4.5-1.

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| **Company** | **Comment** |
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## DMRS

The following views were expressed about the DMRS scheme that should be applied for OCC:

**DMRS multiplexing type**

* CDM: QC, ETRI, ZTE, LGE, NEC
  + Improved channel estimation at 15kHz [CATT]
  + Minimal SNR loss in simulated results for OCC2 [QC][OPPO][ZTE][CMCC]
    - Minimal SNR loss at 15kHz [HW][OPPO]
    - Large SNR loss at 3.75kHz [HW]
  + Loss of orthogonality for DMRS combining due to phase rotation [MTK]
  + Create by spreading DMRS sequence and then applying OCC [QC]
  + Create by masking legacy DMRS sequence with OCC sequence [vivo]
* TDM: HW, ETRI, MTK
  + > 0.2dB loss compared to CDM for symbol-level OCC2 (CFO assumed): QC
  + >1dB loss compared to CDM for OCC4 (CFO assumed): QC
  + 15kHz
    - OCC2: performance loss compared to CDM
      * 1.5dB [HW]
      * 0.8dB [ZTE]
      * 1dB [OPPO]
      * 0.5dB [CATT]
    - OCC4: performance loss compared to CDM
      * 3dB [HW]
      * 2dB [ZTE]
      * 0.3dB [CATT]
  + 3.75kHz
    - OCC2:
      * TDM is 2.7dB better than CDM due to multi-user interference with CDM with CFO [HW]
      * CDM is 0.8dB better than CDM [ZTE]
      * CDM is 2dB better than TDM, but error floor in results [OPPO]
      * CDM is about 0.5dB better than TDM [QC]
  + Performance loss is due to increased combining gain of DMRS with CDM scheme: QC
  + DMRS muting loss [Lenovo]
  + Phase discontinuity between DMRS from a UE [LGE]
    - Due to non-contiguous transmissions
  + Large time gap between consecutive transmitted TDM DMRS leads to performance loss [LGE]
  + Create by masking legacy DMRS sequence with 1/-1/0 pattern [vivo]
  + ON / OFF time mask requires work in RAN4. Without time mask update, there could be distortion [LGE]
  + TDM mapping:
    - UE1 has two consecutive legacy DMRS followed by UE2 [CMCC][HW]
      * Shorter timespan for a UE avoids wrap-around [CMCC][HW]
    - UE1 and UE2 have alternate legacy DMRS
* Multi-tone
  + Cyclic shifts [HW]
    - Existing cyclic shift mechanism can be used [HW]
  + OCC2:
    - TDM [CMCC]
  + OCC4:
    - TDM + FDM (or + comb-like) [CMCC]

The main decision point is between whether the DMRS for an OCC-pair of UEs should be multiplexed via TDM or via CDM. The difference between the structures of the TDM and CDM approaches was illustrated by various companies. Figure 9 is an example illustration from [ZTE]. In the CDM approach, each UE transmits in each of the DMRS locations and the DMRS from the different UEs are separated by an OCC applied to the DMRS transmissions. An important distinction for the CDM structure is whether the DMRS symbols are spread before OCC is applied or whether OCC is applied on DMRS in the legacy locations (this latter approach is what is shown in Figure 9). In the TDM approach, one UE is assigned one DMRS location and the other UE is assigned the other DMRS locations: UE1 blanks its DMRS transmission while UE2 is transmitting DMRS.



(a) structure of CDM DMRS



(b)structure of TDM DMRS

Figure 9 – Structure of TDM and CDM multiplexing schemes (from R1-2407936 – ZTE)

Most companies that simulated performance show a performance loss for TDM relative to CDM [QC,ZTE,HW,CATT]. The loss is generally accepted to be due to the lower DMRS power transmitted in the TDM scheme. Even less TDM DMRS power is transmitted for OCC4, due to the UE transmitting only 1 in 4 of the available DMRS (for OCC2, a UE would transmit 1 in 2 DMRS and for the baseline, it would transmit all DMRS). The loss for TDM is hence greater for OCC4. However, Huawei observed a performance loss for CDM at 3.75kHz SCS, attributing this loss to the greater multi-user interference caused by the combination of the CDM scheme and CFO (at 3.75kHz, there is a greater phase error between DMRS due to the longer timespan). LGE were concerned that TDM would introduce phase discontinuity into the UE’s transmission, which would harm the OCC scheme (other companies noted elsewhere that non-transmission to account for UL NTN segment gaps, UL gaps or NPRACH occasions would cause problems for OCC operation, so it would seem plausible that a gap caused by TDM blanking would also cause a problem).

Based on the agreement at RAN1#118, RAN1 will choose a combination of {OCC scheme, DMRS scheme} based on a list of options. It is hence not appropriate to have a proposal on whether CDM or TDM is preferred. However, a comments box is provided below for those who would like to comment on the above analysis of inputs.

**[FL1] Comments for 4.6-1: Please provide comments on your preference between TDM and CDM multiplexing schemes.**

Companies are invited to comment on 4.6-1.

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| **Company** | **Comment** |
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In RAN1#118, there was an agreement to consider {OCC scheme, DMRS scheme} together based on list of options. We should come to a conclusion on the choice of {OCC scheme, DMRS scheme} before getting into details of the structure of the DMRS schemes. It was commented in the IoT-NTN FLS in RAN1#118 that we should decide on a scheme before getting into the details of the design of the schemes.

The following is a summary on inputs on DMRS patterns.

**3.75kHz DMRS pattern**

A blue squares on a white background

Description automatically generated

* Within cluster separation is x1 symbols, between cluster separation is x2 symbols [QC][NEC]
  + X1 maintains pull-in range, x2 retains DMRS density [QC]
  + X1 should be less than or equal to 8 symbols for CFO / pull-in range reasons [NEC]
  + M consecutive symbols assigned to DMRS; start symbol of a set of DMRS is a multiple of M [QC]
  + Support pattern in the figure above [QC]
  + Slot-level OCC cannot be used as the slots have different structures [HW]
  + For OCC2: [LGE]
    - Slot index mod 2 = 0: DMRS in OS#6
    - Slot index mod 2 = 1: DMRS in OS#0
  + For OCC4: [LGE]
    - Slot index mod 4 = 0: DMRS in OS#5, OS#6
    - Slot index mod 4 = 1: DMRS in OS#0, OS#1
    - Slot index mod 4 = 2 or 3: no DMRS
  + New DMRS scheme will lead to implementation work at eNB [Nok]
* New DMRS pattern is required [QC][Ericsson][NEC][LGE][ETRI]
* Distance between corresponding DMRS must be <= 8 symbols [NEC]
  + Based on CFO = 0.1ppm [NEC]
* Legacy DMRS pattern with different DMRS sequences for different OCC index [Nok]
* Proposal to clarify new DMRS pattern spreading [QC]
  + For 3.75kHz SCS and an OCC order of M, the DMRS pattern is defined as a set of positions within an RU, with the following constraints:
    - M consecutive symbols are allocated to DMRS.
    - The start symbol of a set of DMRS symbols is a multiple of M.

**15kHz DMRS pattern**

* Legacy DMRS pattern used [NEC][LGE][Nok][QC]
  + New pattern will lead to alignment problem between UEs [Nok]
  + New DMRS scheme will lead to implementation work at eNB [Nok]
  + Legacy pattern is legacy pattern before OCC [QC]
* Distance between corresponding DMRS must be <= 35 symbols [NEC]
  + Based on CFO = 0.1ppm [NEC]
* Legacy DMRS pattern with different DMRS sequences for different OCC index [Nok]

## UL gaps

The following issues were raised related to the impact of UL gaps on OCC operation:

* Need to align OCC around transmission gaps [QC]
* Need to accurately align UEs if their NPUSCH starting times cause gaps to occur at different times [QC]
* Align OCC DMRS such that they don’t straddle a gap [QC]
* Postpone around an UL gap [Ericsson]
* OCC does not span UL NTN segment gaps [LGE][Nok][vivo][Spreadtrum][HW]
  + There is pre-compensation within an UL segment and phase continuity is not maintained between UL segments [LGE][Nok]
  + Drop any OCC codeword that at least partially spans an UL segment gap [Nok]
* Approaches to mitigate gaps in OCC transmissions:
  + OCC sequences that are robust to time misalignment [Ericsson]
  + Timing correction / control functionality at UE transmitter [Ericsson]
  + Receiver processing techniques to compensate for distortion in gaps [Ericsson]
* RAN4 issues
  + Send LS to RAN4 requesting information on stability of UE CFO over time and across gaps [Sony]
    - Currently no CFO stability requirements in RAN4 and these might affect performance of long transmissions or re-transmissions [Sony]
* UL gaps for synchronization (from Rel-13)
  + Drop OCC segment that spans gap [Spreadtrum][vivo]
  + Phase continuity broken across gap [vivo]
  + eNB does not schedule UE with OCC if the NPUSCH would span a gap [vivo]
  + Consider in design / further study [CMCC][CATT][ETRI]
  + OCC is orthogonal both before and after a gap [Apple]
* Gaps around NPRACH occasions
  + Drop OCC segment that spans gap [Spreadtrum]
  + Consider in design / further study [CMCC][CATT]
  + NPRACH and UL gaps require postponements [Ericsson]
  + Align OCC scheme around NPRACH gaps [QC]
* UL timing adjustment gaps and segmentation for IoT-NTN (from Rel-17)
  + Drop OCC segment that spans gap [Spreadtrum][Apple]
  + OCC does not span UL segment gap [vivo]
  + Study how to put gaps and segments in appropriate places to avoid dropping issues [CATT]
  + UL TA gaps are not an issue if segment length is a multiple of OCC length [MTK]
  + Consider in design [CMCC][Apple][ETRI]
* TDM DMRS that are muted
  + No issue [Spreadtrum][vivo][CMCC][CATT]
    - < 13 OFDM symbols (from NR coverage enhancement work), hence phase continuity is maintained [vivo]
* Guard periods for 3.75kHz UL transmissions
  + No issue [Spreadtrum] [CMCC][ETRI]
    - Gap length is very short and not significant phase rotation [Spreadtrum][ETRI]
    - < 13 OFDM symbols (from NR coverage enhancement work), hence phase continuity is maintained [vivo]

There are several (potentially related) problems with UL gaps. Firstly, it is necessary to ensure that an OCC transmission does not span a gap as this will leave part of the OCC codeword on one side of the gap and the other part of the codeword on the other side of the gap. Secondly, UL gaps may occur at different times for different UEs – there may need to be alignment such that both UEs in an OCC pair are transmitting consistently. Thirdly, there is likely to be phase discontinuity on either side of an UL transmission gap – this will introduce loss of orthogonality between UEs.

The following types of gap have been identified in RAN1#118. FL summary comments on the issues related to these gap types are included.

* UL gaps for synchronization (from Rel-13)
  + Issues identified. Further study required in RAN1. Detailed OCC scheme design may need to account for these gaps.
* Gaps around NPRACH occasions
  + Issues identified. Further study required in RAN1. Detailed OCC scheme design may need to account for these gaps.
* UL timing adjustment gaps for NTN (from Rel-17)
  + Issues identified. Further study required in RAN1. Detailed OCC scheme design may need to account for these gaps.
* TDM DMRS that are muted
  + No issue
* Guard periods for 3.75kHz UL transmissions
  + No issue

Based on this summary, it is proposed that RAN1 observes that TDM DMRS (if supported) and guard periods for 3.75kHz UL transmissions do not impact phase continuity.

**[FL1] Proposed observation 4.7-1: From the perspective of phase continuity, the following do not affect the design of OCC for IoT-NTN:**

* **TDM DMRS that are muted**
* **Guard periods for 3.75kHz UL transmissions**

Companies are invited to comment on proposed observation 4.7-1.

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| **Company** | **Comment** |
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## Other features that should work with OCC

The following features were identified as being features OCC should be compatible with:

* Connected mode dynamic grant [QC]
* EDT [QC][TCL]
* PUR [QC][TCL]
  + Consider relationship of OCC to “shared PUR” in Rel-16 [Ericsson]
* RACH-less EDT (R19) [QC]
* Compatibility and coexistence between OCC and non-OCC UEs [Nok]

At this stage of the work item, it would seem like it would be good to focus on the fundamental design of OCC. Hence, FL proposes that the this list of compatible features can be considered later in the work item.

**[FL1] Question 4.8-1: Can RAN1 consider which features OCC should work with (EDT, PUR) at a future meeting (as opposed to at RAN1#118bis)?**

Companies are invited to comment on question 4.8-1.

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| **Company** | **Comment** |
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## Signalling

There are various aspects related to OCC that need to be signalled to the UE. These aspects have been identified in various documents:

* Aspects that need to be signalled:
  + OCC factor (M) [QC][ETRI] [Sharp]
  + OCC codeword [QC][Sharp][TCL]
  + OCC feature enabling [QC][Sharp][TCL]
  + Sequence type (DFT or Walsh) [ETRI]
* RRC [ETRI][Spreadtrum]
  + OCC feature enabling [QC][TCL]
  + OCC factor (M) [QC] [ETRI]
* DCI [ETRI][Sharp][Speradtrum]
  + OCC codeword [QC][Sharp][TCL]
  + OCC feature enabling [Sharp]
    - Allows fast switch between OCC scheme and legacy NPUSCH [Sharp]
  + Maintain DCI size [Sharp][TCL]
    - Does not increase blind decoding effort at UE [Sharp]
    - Reinterpretation of DCI fields [Sharp]
      * Reinterpret bits in MCS field [TCL]
* MAC CE
* Implicitly derived

At this stage, it would be useful to identify which aspects of OCC need signalling to the UE. At a later stage, we can decide how these aspects are signalled.

A potential list of items to be signalled is:

* OCC factor (M)
* OCC codeword (e.g. for OCC2, whether the UE uses code [1,1] or [1,-1])
* OCC feature enabling
* OCC scheme (whether cross-slot or cross-symbol etc., although FL assumes that only one scheme would be specified and this signalling would not be necessary).

The general view in RAN1#118 was that these signalling details could be considered once a baseline scheme had been identified for the OCC schemes. Hence, FL proposes to consider these issues at a future meeting.

**[FL1] Question 4.9-1: Can RAN1 consider signalling for OCC at a future meeting (as opposed to at RAN1#118bis)?**

Companies are invited to comment on question 4.9-1.

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| **Company** | **Comment** |
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## Pairing

The following issues related to pairing of UEs were identified:

* RAN1 study potential loss of orthogonality from pairing UEs [Ericsson]
* Factors to be considered for pairing:
  + Traffic characteristics [Ericsson]
  + Number of repetitions [Ericsson]
  + Modulation schemes [Ericsson]
  + Location [Ericsson]
  + Power [Ericsson]
* Can be solved by network for NPUSCH [Spreadtrum]
  + E..g based on CQI in Msg3 [Spreadtrum]

It is unclear whether these issues would affect the specification or whether they are just issues that should be considered in the evaluations. Most companies at RAN1#118 considered that pairing can be up to network implementation. If the network were to need any help in pairing UEs, maybe this could be considered as a lower priority issue compared to the more fundamental issues of choice of OCC scheme etc.

**[FL1] Question 4.10-1: Can RAN1 consider issues related to pairing of UEs for OCC at a future meeting (as opposed to at RAN1#118bis)?**

Companies are invited to comment on question 4.10-1.

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| **Company** | **Comment** |
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## Downlink Issues and alignment

The following issues related to the **downlink** have been identified:

* Increase in NPDCCH resource [Ericsson]
  + 4 OCC NPUSCH requires 4 DCIs [Ericsson]
* Alignment of NPUSCH requires staggered NPDCCH, requiring new k0 values (subframes between NPDCCH and NPUSCH) [Ericsson]
* NPUSCH from different UEs need alignment [Nok]

A related issue is that of **alignment** of the OCC transmissions in general, where the following issues were identified:

* Alignment of NPUSCH requires staggered NPDCCH, requiring new k0 values (subframes between NPDCCH and NPUSCH) [Ericsson]
* Reference point in time introduced to align OCC from different UEs [TCL]
* Alignment of adding new UEs with OCC to existing group of UEs already doing OCC [QC]
* Alignment of codewords around OCC gaps [QC]
* New DMRS schemes will lead to difficulty of alignment of UEs. [Nok]
  + Applies to both TDM and CDM [Nok]

In RAN1#118bis, companies generally commented that we do not need to consider improvements to downlink signalling at this stage. In this meeting, it appears that there is a greater set of alignment issues that needs to dealt with, including:

* Alignment of start times of NPUSCH, including how to signal OCC NPUSCH with a limited number of NPDCCH
* Alignment of adding new UEs to an ongoing OCC operation, including alignments of OCC codewords and DMRS
* Alignment of OCC operation with UL gaps

It would seem that these issues can be considered at a future meeting, once the baseline OCC schemes have been defined.

**[FL1] Question 4.11-1: Can RAN1 consider issues related to alignment of OCC transmissions at a future meeting (as opposed to at RAN1#118bis)?**

Companies are invited to comment on question 4.11-1.

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| **Company** | **Comment** |
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# NPRACH (to be updated)

## Overall summary of issues raised in Tdocs

The following is an overall summary of issues raised by companies in input contributions to RAN1#118bis. Note that there were not many significant changes to the issues identified in RAN1#118.

**Support or not**:

* Support [QC][Lenovo][NEC][Nordic]
* Not support [Ericsson][CATT][Spreadtrum][TCL][MTK][Samsung]
  + Reasons:
    - Backward compatibility [Ericsson]
    - Specification impact [Ericsson][CATT][Spreadtum][HW]
    - NPRACH is not the bottleneck [CATT][Spreadtrum][HW]
    - Performance with power imbalance, timing error [HW]
    - R19 EDT will not require Msg1, so OCC enhancement not required [MTK]

**OCC scheme**

* Cross-symbol [QC][ETRI][NEC][Lenovo][ZTE][Nordic]
  + 0.2dB penalty from OCC3 with 3 UEs while increasing multiplexing factor by 3 [QC]
  + 1dB penalty from 2 UEs with OCC5 [ETRI]
  + 3dB penalty from 4 UEs with OCC5 [ETRI]
  + Penalty < 0.5dB for OCC in range of 2 to 5 [ZTE]
  + Big change to NPRACH structure, including adding CP symbols [CATT][Xiaomi][TCL][Spreadtrum] [MTK]
  + For OCC2, adding a CP in the 4th symbol of the SG is a simple change [NEC]
  + Allows TO and FO estimation at eNB [ZTE]
  + 5 symbol structure makes use of length-4 Walsh codes difficult [Spreadtrum]
* Cross-symbol group [Sharp][NEC][Lenovo][Xiaomi]
  + Time span is too long and leads to loss of orthogonality [QC][CATT][Spreadtrum][HW][MTK]
  + Simple to implement [Sharp]
  + OCC2 and OCC4 can be easily supported [Sharp]
  + FH
    - Modified FH mechanism [NEC]
    - FH can lead to loss of orthogonality [Nok][CATT][vivo][HW]
  + Time and frequency offset estimation difficult at eNB [ZTE][HW]
  + Power inconsistency between hops can lead to imbalance [MTK]
* Cross repetition
  + Note that it was agreed in RAN1#117 that this will not be considered [FL]

**OCC factors (M)**

* 2 [Sharp][NEC]
* 3 [QC]
* 4 [Sharp]
* 5 [ETRI]
* Note: the value chosen will probably depend on the NPRACH scheme (symbol vs SG etc) [FL]

**Multiplexing of legacy UEs and OCC UEs**

* Allow [QC][Nordic]

**Features that OCC should work with**:

* Initial access [QC]
* EDT [QC]
* PDCCH order [QC]
* Connected mode CBRA [QC]

**RAR**

* RAR impact of OCC needs to be taken into account [QC][TCL][HW]
  + RAPID needs to account for OCC [Ericsson][LGE]
  + RAR impacts would cause workload in RAN2 [Samsung]
* Separate RA-RNTI for NDPDSCH-RAR for OCC UEs [LGE]
  + Allows the MAC PDUs for legacy and OCC UEs to be differentiated [LGE]

**NPRACH resource**

* Dedicated NPRACH resources for OCC [Apple][Ericsson][ETRI][Interdigital]
  + Avoids clash between legacy UEs and OCC UEs [Apple][Ericsson]
    - Clash occurs when symbols within symbol group are repeated since FH pattern would then be different between legacy and OCC UEs [Ericsson]
* Use all-1s OCC codeword for legacy UEs within NPRACH multiplexing scheme [QC]
* UEs with similar DL RSRP measurements can be OCC-ed together [LGE]

**Performance requirements**

* RAN4 performance requirements on false preamble detection need updating [Ericsson]

**Signalling**

* Sequence type [ETRI]
* Repetition and spreading level [ETRI]
* Sequence length [ETRI]
* Whether cross-symbol or cross-SG [Lenovo]
* Channel for configuration
  + NPDCCH [ETRI]
  + RRC unicast
  + SIB
* Separate configuration for each coverage level [Lenovo]

**Anchor and non-anchor carrier selection probability**

* Study if the anchor carrier and non-anchor carrier selection probabilities need enhancing [NEC]
  + Account for there being effectively more NPRACH resources if OCC is applied to some of the carriers

**Stricter timing and frequency synchronisation**

* Needed to avoid the orthogonal properties of OCC [NEC]

Note: these issues will be discussed in a future version of this FLS.

# Conclusions

This document is the feature lead summary for IoT-NTN in RAN1#118bis. It contains the FLS discussion and lists the proposals that were considered in online sessions.

# References

[1] RP-241624, “Revised WID on Non-Terrestrial Networks (NTN) for Internet of Things (IoT) Phase 3”, MediaTek Inc. (Rapporteur), RAN#104, June 17-20, 2024

[2] R1-2407563 “Final FL Summary for IoT-NTN”. RAN1#118, Maastricht, Netherlands. Moderator (Sony)

[3] R1-2401298 “Work Plan for Rel-19 IoT NTN”. Mediatek (rapporteur)

R1-2407663 Discussion on UL capacity enhancements for IoT NTN Huawei, HiSilicon

R1-2407724 Discussion on IoT-NTN uplink capacity/throughput enhancement Spreadtrum Communications

R1-2407881 Discussion on IoT-NTN uplink capacity enhancement vivo

R1-2407923 Discussion on the IoT -NTN uplink capacity/throughput enhancements CMCC

R1-2407936 Discussion on UL capacity enhancement for IoT NTN ZTE Corporation, Sanechips

R1-2407959 Discussion on IoT-NTN uplink capacity enhancement Xiaomi

R1-2408036 Discussion on UL capacity enhancement for IoT NTN CATT

R1-2408138 Discussion on IoT-NTN uplink capacity/throughput enhancement OPPO

R1-2408229 IoT-NTN uplink capacity/throughput enhancement NEC

R1-2408243 Discussion on the IoT-NTN uplink capacity/throughput enhancements TCL

R1-2408301 Discussion on IoT-NTN uplink capacity/throughput enhancement LG Electronics

R1-2408324 Discussion on uplink capacity enhancement for IoT NTN Lenovo

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R1-2408555 IoT-NTN uplink capacity/throughput enhancement InterDigital, Inc.

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