**3GPP TSG RAN WG1 #117 DRAFT\_R1-2405494**

**Fukuoka, Japan, 20th-24th May 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

**Main Introduction**

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

At this initial stage of the work, the goal is to have an “Study the benefit and identify the options for usage of OCC on NPUSCH and NPRACH”, as stated in the workplan [2].

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 evaluations**. Simulation results of the previously agreed OCC schemes.
* **Choice of OCC schemes**. Can we choose a single scheme to further consider based on evaluations and workload?
* **DMRS evaluations**. Comparison of CDM and TDM schemes.
* **DMRS**. Can we choose between CDM and TDM DMRS? Where should the DMRS symbols be located?
* Other issues that do not have to be discussed at this stage are also listed (signalling, configuration, UL segments and compatibility with other features)

**NPRACH**

The following issues are discussed for NPRACH:

* **OCC evaluations**. Simulation results of the previously agreed OCC schemes.
* **Choice of OCC schemes**. Do we need to further consider repetition-level OCC?
* **NPRACH vs NPUSCH priority**. Whether we should prioritise NPUSCH OCC over NPRACH OCC.
* Other issues that do not have to be discussed at this stage are also listed.

Follow the naming convention in this example:

* *IoTNTNFLS1-v000.docx*
* *IoTNTNFLS1-v001-CompanyA.docx*
* *IoTNTNFLS1-v002-CompanyA-CompanyB.docx*
* *IoTNTNFLS1-v003-CompanyB-CompanyC.docx*

If needed, you may “lock” a discussion document for 30 minutes by creating a checkout file, as in this example:

* Assume CompanyC wants to update *IoTNTNFLS1-v002-CompanyA-CompanyB.docx*.
* CompanyC uploads an empty file named *IoTNTNFLS1-v003-CompanyB-CompanyC.checkout.*
* CompanyC checks that no one else has created a checkout file simultaneously, and if there is a collision, CompanyC tries to coordinate with the company who made the other checkout (see, e.g., contact list below).
* CompanyC then has 30 minutes to upload *IoTNTNFLS1-v003-CompanyB-CompanyC.docx.*
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In file names, please use the hyphen character (not the underline character) and include ‘v’ in front of the version number, as in the examples above and in line with the general recommendation, otherwise the sorting of the files will be messed up (which can only be fixed by the RAN1 secretary).

To avoid excessive email load on the RAN1 email reflector, please note that there is NO need to send an info email to the reflector just to inform that you have uploaded a new version of this document. Companies are invited to enter the contact info in the table below.

Issues for which comments are invited in this FLS are labelled with [FL3].

The table below provides a list of points of contact within companies for this WI. Contact details from RAN1#116bis Changsha use a blue font. Please feel free to update your contact details and convert into a black font.

**[FL1][FL2]** [**FL3**] **Please consider entering contact info below for the points of contact for this email discussion.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Point(s) of contact** | **Email address(es)** |
| SONY | Martin Beale | martin.beale@sony.com |
| Ericsson | Gerardo Agni Medina Acosta | gerardo.agni.medina.acosta@ericsson.com |
| Lenovo | Zhi Yan | yanzhi1@lenovo.com |
| LGE | Daesung Hwang  Seungmin Lee  Hanjun Park | daesung.hwang@lge.com  edison.lee@lge.com  hanjun0128.park@lge.com |
| Gatehouse Satcom | René Brandborg Sørensen | rbs@gatehouse.com |
| Nokia, NSB | Jingyuan Sun | Jingyuan.sun@nokia-sbell.com |
| InterDigital, Inc | Umer Salim | [umer.salim@interdigital.com](mailto:umer.salim@interdigital.com) |
| ETRI | Pansoo Kim | pskim@etri.re.kr |
| vivo | Zichao Ji  Siqi Liu | [jizichao@vivo.com](mailto:jizichao@vivo.com)  [liusiqi@vivo.com](mailto:liusiqi@vivo.com) |
| Sharp | Zhanping Yin | zyin@sharplabs.com |
| Xiaomi | Xuemei Qiao | qiaoxuemei@xiaomi.com |
| Spreadtrum | Lei Gu | Lei.gu@unisoc.com |
| TCL | Yu Ding  Yiwei Deng | [yu10.ding@tcl.com](mailto:yu10.ding@tcl.com)  yiwei1.deng@tcl.com |
| ZTE | Nan Zhang  Fangyu Cui  Ziyang Li | [zhang.nan152@zte.com.cn](mailto:zhang.nan152@zte.com.cn)  [cui.fangyu@zte.com.cn](mailto:cui.fangyu@zte.com.cn)  Li.ziyang1@zte.com.cn |

# WID objectives

The IoT-NTN WID [1] 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]     - Multi-tone support for 15 kHz SCS should also be considered   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 EDT transaction [RAN2]:     - Msg3 transmission without msg1/RAR     - Efficient delivery (reduced overhead) of msg4 / RRCEarlyDataComplete |

# Previous agreements

The following agreements were made in RAN1#116 Athens:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 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:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 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. | |

# NPUSCH

## Overall summary of issues raised in Tdocs

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

* NPUSCH evaluation results
  + Single-tone OCC evaluation results:
    - 15kHz [Huawei, vivo, ZTE, Xiaomi, Oppo]
    - 3.75kHz [Huawei, QC]
  + Multi-tone evaluation results: [Huawei, vivo, ZTE, CATT, Xiaomi, Oppo]
* DMRS multiplexing schemes:
  + Views on CDM vs TDM [Spreadtrum, HW, vivo, ZTE, LGE, CATT, Lenovo, Ericsson, NEC, ETRI, Oppo, Qualcomm]
  + Cyclic-shift based for multi-tone [HW, Nokia]
  + Location of DMRS symbols [Ericsson, Qualcomm, NEC, LGE]
  + Evaluation results for CDM and TDM DMRS [HW, ZTE, Oppo]
* Configuration of OCC scheme
  + OCC scheme can be configured by network [Lenovo, NEC, Sharp, ETRI]
* Signalling of OCC sequence
  + DCI, semi-static (RRC) or based on C-RNTI
* Types of OCC sequence
  + DFT codes [ZTE, Apple]
    - From PUCCH format 1 in TS38.211 [ZTE]
  + Walsh codes [CATT, Apple]
* OCC size
  + Maximum 4 [Apple]
    - NPDCCH signalling would be the bottleneck if we supported more than OCC4 [Apple]
      * NPDCCH needs to schedule NPDSCH as well as NPUSCH [Apple]
  + Maximum 2 [Ericsson]
    - Phase shift is too large for OCC4 [Ericsson]
  + 2,4 [Apple]
  + Support a limited number of OCC lengths [Nokia]
    - Supporting too many OCC lengths would increase complexity [Nokia]
* Views on OCC schemes for NPUSCH
  + Most companies expressed preferences. These have been discussed in previous meetings (see [3]). We now have some evaluation results that we can use to decide on a scheme.
* Segments
  + Consider the effects of UL segments on OCC operation [spreadtrum ,LGE, Nokia, Ericsson]
    - There will be loss of phase continuity between segments [spreadtrum, LGE]
    - If OCC spans a dropped symbol within a segment gap, the whole segment is dropped, otherwise there will be a loss of orthogonality from a partial OCC unit [Nokia]
* Other features (other than connected mode dynamic grant) with which NPUSCH OCC should work
  + IDLE / INACTIVE (including EDT) [Xiaomi]
    - Xiaomi are unsure whether OCC applies to these cases in the current WID
  + EDT [QC, TCL]
  + PUR [QC, TCL]
  + RACH-less EDT (Rel-19) [QC]
* Compatibility and coexistence with legacy UEs [Nokia]
* NPRACH periodicity
  + NPUSCH with OCC should fit within NPRACH periodicity [Ericsson]
* Odd NPUSCH scheduling delays [Ericsson]
  + NPDCCH should be able to signal odd subframe offset to increase the number of scheduling opportunities for NPUSCH [Ericsson]

## Evaluation results on OCC schemes

The specific details of the simulations are contained within the Tdocs. The evaluations vary depending on the assumptions, including the choice of LEO/GEO, format used (number of RU, number of repetitions, TBS), choice of DMRS scheme, details of how each scheme is implemented etc. Hence, the tables below shows the SNR degradation of each scheme from the baseline scheme of no OCC at a 10% BLER operating point.

**15kHz single-tone**

Evaluation results were provided on the following OCC schemes for 15kHz single-tone:

* Time domain OCC where OCC spreads across:
  + Symbol-level [Huawei, vivo, ZTE, Oppo]
  + Slot-level [Huawei, vivo, ZTE, Oppo]
  + Repetition-level / RV-level [Huawei, vivo, ZTE, Xiaomi]

Table 1 – 15kHz single tone: SNR degradation for OCC schemes

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **OCC2** |  |  | **OCC4** |  |  |
| **Company** | **Symbol** | **Slot** | **Rep/RV** | **Symbol** | **Slot** | **Rep/RV** |
| **Huawei** | 0.30 | 0.36 | 3.18 | 1.56 | 1.86 | 5.19 |
| **Vivo** | 3.2 | 3.2 | 3.5 |  |  |  |
| **ZTE** | 0.3 | 0.3 | 0.3 | 1.6 | 1.8 | 1.9 |
| **Xiaomi** |  |  | 0.9 |  |  | 4.1 |
| **Oppo** | 0.3 | 0.5 |  |  |  |  |

Notes: Huawei results are shown for their best-performing DMRS scheme (TDD). Vivo report in their text that the code rate is increased for their symbol-level and slot-level schemes.

The following observation is drawn: there is significant performance degradation as the time-span of the OCC scheme increases. This observation is based on the results from Huawei, ZTE and Xiaomi (comparing OCC2 and OCC4) and the results from Huawei (comparing the symbol-level and slot-level schemes to the rep-/RV-level schemes). The discussion text from vivo indicates that their symbol-level and slot-level schemes lead to an increase in code rate as OCC is applied, leading to a drop in symbol-level / slot-level performance. FL understands that other companies assume that changes to physical channel mapping would mean that this loss of code rate would not happen.

The table below allows companies who provided simulation results to comment on the FL’s summary table in Table 1.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| vivo | In our simulation, the code rate is increased for some OCC schemes because we want to ensure that the time spanning of the PUSCH transmission is the same as the baseline. Of course, the performance degradation can be avoided if more time resources are scheduled to maintain the same code rate. However, we think it is more important to minimize the mapping changes considering the spec efforts. If expanding time-domain resources mapping is necessary to achieve the benefits of OCC, then why not simply schedule UEs in a TDM manner? |
|  |  |
|  |  |
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|  |  |

**3.75kHz single-tone**

Evaluation results were provided on the following OCC schemes for 3.75Hz single-tone:

* Time domain OCC where OCC spreads across:
  + Symbol-level [Huawei, Qualcomm]
  + Slot-level [Huawei]
  + Repetition-level / RV-level [Huawei]

Table 2 – 3.75kHz single tone: SNR degradation for OCC schemes

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **OCC2** |  |  | **OCC4** |  |  |
| **Company** | **Symbol** | **Slot** | **Rep/RV** | **Symbol** | **Slot** | **Rep/RV** |
| **Huawei** | 0.83 | 1.23 | 8.03 | 5.49 | 6.01 | large |
| **Qualcomm** | 0.0 |  |  | 0.43 |  |  |

Notes: Huawei results are shown for their best-performing DMRS scheme (TDD).

The following observation is drawn: there is significant performance degradation as the time-span of the OCC scheme increases. This is evident from the degradation between OCC2 and OCC4 for the results from both companies. The Huawei results also show that as the time-span of the scheme increases (symbol-level -> slot-level –> rep/RV-level), the performance degradation increases.

The table below allows companies who provided simulation results to comment on the FL’s summary table in Table 2.

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

**15kHz multi-tone**

Evaluation results were provided on the following OCC schemes for 15kHz multi-tone:

* Time domain OCC where OCC spreads across:
  + Symbol-level [Huawei, vivo, ZTE, CATT, Oppo]
  + Slot-level [Huawei, vivo, ZTE, CATT, Oppo]
  + Nslot-level [Huawei, vivo, ZTE, Xiaomi]
  + RV-level [Huawei, vivo]
* Intra-symbol pre-DFT spreading OCC [Huawei, vivo]

Table 3 – 15kHz multi-tone: SNR degradation for OCC schemes

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **OCC2** |  |  |  |  | **OCC4** |  |  |  |  |
| **Company** | **Intra-symbol** | **Symbol** | **Slot** | **Nslot** | **RV** | **Intra-symbol** | **Symbol** | **Slot** | **Nslot** | **RV** |
| **Huawei** | 0.79 | 0.72 | 0.94 | 1.17 | large | 0.77 | 0.47 | 2.57 | 8.43 | large |
| **Vivo** | 2.7 | 3.5 | 1.3 | 1.3 | 1.3 |  |  |  |  |  |
| **ZTE** |  | 0 | 0 | 0 |  |  | 0.3 | 0.5 | 0.7 |  |
| **CATT** |  | 3.5 | 3.8 |  |  |  |  | 3.6 |  |  |
| **Xiaomi** |  |  |  | 1.8 |  |  |  |  | 8.0 |  |
| **Oppo** |  | 0.5 | 0.5 |  |  |  |  |  |  |  |

Notes: Huawei results are shown for their best-performing DMRS scheme (TDD). Vivo report in their text that the code rate is increased for their symbol-level and slot-level schemes.

The following observation is drawn: there is significant performance degradation as the time-span of the OCC scheme increases. This is evident from the degradation between OCC2 and OCC4 for the results from Huawei, ZTE and Xiaomi. It is also shown in the results from Huawei based on the performance degradation as the timespan of the OCC scheme increases (from intra-symbol level through to RV-level). An outlier is the result from vivo. The discussion text from vivo indicates that their symbol-level schemes lead to an increase in code rate as OCC is applied, leading to a drop in symbol-level / slot-level performance. FL understands that this increase in code rate could be avoided based on changes to physical channel mapping.

The table below allows companies who provided simulation results to comment on the FL’s summary table in Table 3.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| vivo | We also provided simulation results of RV-level OCC, FL already captured our results in the table but missed including our name in the bracket.   * + RV-level [Huawei, vivo]   For this case, we also think that minimizing mapping changes is more crucial than extending the time resource to maintain the same code rate. |
|  |  |
|  |  |
|  |  |
|  |  |

**Overall observations**

**[FL1] Observation 4.2-1: The performance of the OCC schemes degrades as the time span of the schemes increases (symbol-level through to RV-level).**

Companies are invited to comment on observation 4.2-1. Note that there is no intention to reach an agreement on this observation in the meeting.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Lenovo | Is the observation for NPUSCH format 1 OCC scheme? We are OK with the observation in general, but when we do down-selection for the OCC scheme, we should not only consider the performance (e.g., uplink system overall capacity increase? Per-UE SNR performance? What kind of performance) but also consider the standard impact, compatibility with legacy system, etc. |
| Spreadtrum | Fine with the observation. |
| FL [FL2][FL3] | Lenovo> Yes, it refers to NPUSCH format 1. It would be clearer if the observation said:  **Observation 4.2-1v1: For NPUSCH format 1, the performance of the OCC schemes degrades as the time span of the schemes increases (symbol-level through to RV-level).**  Let’s please bear in mind that we aren’t going to try to get these observations agreed in the main meeting. |
| vivo | The simulation results are performed with frequency error, thus, we suggest to add “when frequency error is considered”. In addition, as FL explained before, the observations is not true when the code rate for intra-slot OCC schemes is increased, so we suggest adding the same code rate in the proposal  **Observation 4.2-1v1: For NPUSCH format 1, when frequency error is considered, the performance of the OCC schemes with the same code rate degrades as the time span of the schemes increases (symbol-level through to RV-level).** |
| ZTE | We think the observation is not correct, since the main impact factor is frequency error, and only when the time span increases to a level, the performance starts to decrease for certain assumption, e.g. for OCC-2, performance of slot level has no difference from symbol level. So it’s more appropriate to say  **Observation 4.2-1v1: For NPUSCH format 1, the tolerance to frequency error of the OCC schemes degrades as the time span of the schemes increases (symbol-level through to RV-level).** |

**[FL1] Observation 4.2-2: The SNR performance degradation of OCC4 is greater than the SNR performance degradation of OCC2. Note that there may still be an overall aggregate throughput gain from OCC4.**

Companies are invited to comment on observation 4.2-2. Note that there is no intention to reach an agreement on this observation in the meeting.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Lenovo | It is better to give an explicit observation for OCC 2 and OCC4 on overall aggregate throughput gain. |
| Spreadtrum | Fine with the observation. |
| FL [FL2][FL3] | In line with the previous comment, maybe the observation would be better as:  **Observation 4.2-2v1: For NPUSCH format 1, the SNR performance degradation of OCC4 is greater than the SNR performance degradation of OCC2. Note that there may still be an overall aggregate throughput gain from OCC4.**  I used the SNR at 10% BLER metric (one of the agree KPIs from RAN1#116) as this seemed more consistent and comparable between the results that were provided. For the aggregate throughput curve, I think that companies need to be clear about the SNR operating point at which the aggregate throughput should be measured. The SNR operating point would be a function of coverage. I’m happy to gather these sorts of statistics if companies are clear about the SNR operating point. As far as I could see, only Huawei provided the SNR operating point in their results. |
| Nokia, NSB | Generally support. But for the observation, we think it is good to mention “equal or greater” or anyway to mention how much greater is still not clear. |
| vivo | OK with the observation. |
| ZTE | OK with minor modification:  **Observation 4.2-2v1: For NPUSCH format 1, the SNR performance degradation of OCC4 is greater than the SNR performance degradation of OCC2. Note that there is still be an overall aggregate throughput gain from OCC4.** |

## Choice of OCC scheme

The specification impacts of the schemes have been discussed by various companies. It is generally acknowledged that the schemes with shorter time span (e.g. symbol-level and slot-level) will lead to changes in the physical channel processing chain / resource mapping (for example, repeating symbols or slots). An example summary of the changes required is provided by Huawei (see yellow highlighted cells in the table):

Table 6 Comparison of different OCC schemes (from R1-2403941)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Spec impact | | | RV cycling | Resource mapping | Scheduling restriction | Resource allocation | DMRS |
| RV/Repetition-level | ST | | Same RV across time span of an OCC sequence | No change | time span of an OCC sequence within a segmentation | No change | TDM/CDM |
| MT | | Additional CS |
| Nslot/ Slot level | ST | | No change | repeat slot by occ-length before mapping new slot | time span of an OCC sequence within a segmentation | scale *NRU* or TBS | TDM/CDM |
| MT | Slot-level | Additional CS |
| Nslot level | No change | No change | OCC length may be restricted to  Time span of an OCC sequence within a segmentation | No change |
| Symbol level | ST | | No change | repeat DFT-s-OFDM symbol by occ-length before mapping new symbol | Time span of an OCC sequence within a segmentation  OCC length should divide number of data symbols per slot | scale *NRU* or TBS | TDM/CDM |
| MT | | Additional CS |
| Intra-symbol | ST | | N/A | N/A | N/A | N/A | N/A |
| MT | | No change | pre DFT spreading | OCC length should divide allocated number of subcarriers | scale *NRU* or TBS | Additional CS |

While there are more minor changes from Nslot-level / repetition-level / RV-level schemes, the performance of these schemes is degraded (see section 4.2) compared to the shorter timespan schemes. Furthermore, it is likely that changes will be required to the DMRS structure to support OCC for any of the schemes and these changes will lead to changes in physical channel mapping / resource mapping anyway.

Some companies [Lenovo, NEC, Sharp, ETRI] have raised the issue of whether it should be possible to configure the OCC scheme that is applied (one network might configure symbol-level OCC while another network configures RV-level). This configurability would lead to an increase in specification impact (multiple schemes would need to be specified), UE capability issues (different UEs would report different capabilities in terms of their supported OCC schemes) and further difficulty in pairing UEs for OCC (not only would the network needs to pair UEs with compatible traffic characteristics, numbers of repetitions, modulation schemes, location, power, performance [Ericsson]), but the network would also need to pair UEs based on supported OCC scheme.

For 3.75kHz single tone, the performance degradation with increasing timespan is more critical, hence it is proposed that the shortest timespan OCC scheme is applied, leading to the following proposal.

**[FL1] Proposal 4.3-1: For 3.75kHz single-tone OCC, RAN1 supports symbol-level OCC. Other OCC schemes are not pursued for 3.75kHz single-tone OCC.**

Companies are invited to comment on proposal 4.3-1. Companies could comment on:

* whether they support the proposal
* if there is a different scheme that they would propose as a single scheme
* whether they want to support multiple schemes and have the eNB configure one of the schemes
* whether they are OK to perform some down-selection at this time, but are not yet ready to down-select to a single scheme

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Ericsson | If NPUSCH Format 1 single-tone with 3.75 kHz is intended to be supported, then an OCC symbol-level granularity seems to be a suitable choice. |
| Lenovo | In general, we are OK to support unified solution for single tone OCC and multi-tone OCC if possible, otherwise we can have separate discussion on each case.  Regarding the OCC for 3.75KHz and 15KHz for single tone case, there is no obvious benefit to have different schemes, so it is better to discuss together.  when we do down-selection for the OCC scheme (for both single tone and multiple tone cases), we should not only consider the performance (e.g., uplink system overall capacity increase? Per-UE SNR performance?) but also consider the standard impact, compatibility with legacy system, etc.  Based on that, we should list some trade-off schemes (e.g., symbol level, slot level, etc) with more details compared with previous meeting for further down-selection in next meetings, and it seems the symbol-level based solution is the one extreme among all potential solutions. |
| LGE | In our understanding, the performance difference between symbol-level OCC and slot-level OCC for single-tone NPUSCH with 3.75kHz SCS is less than 1dB. Meanwhile, the slot-level OCC would keep the existing DMRS pattern.  On the other hand, we may need to newly define DMRS pattern to support symbol-level OCC.  To minimize workload, our 1st preference is to support only slot-level OCC.  To bypass 200MHz frequency offset that will affect to OCC orthogonality, it can be considered that eNB estimates the CFO for the reived NPUSCH without OCC, then the eNB indicates applying OCC to NPUSCH when the estimated CFO is less than a certain threshold. |
| Spreadtrum | We think 3.75kHz and 15kHz should be a unified design, so the Proposal 4.3-1 should include “15kHz” as follow.   |  | | --- | | **Proposal 4.3-X: For 3.75kHz and 15kHz single-tone OCC, RAN1 supports symbol-level OCC. Other OCC schemes are not pursued for 15kHz single-tone OCC.** | |
| FL | LGE> Yes, I think the results so far show that the performance difference between symbol-level and slot-level is less than 1dB. I suspect that we could consider the schemes that you suggest in future meetings (reviving CFO etc).  From the responses so far, it seems like either symbol-level or slot-level is OK. Other schemes would be too susceptible to CFO. We could then modify the proposal as:  **Proposal 4.3-1v2:**  **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.** |
| FL\_2 | [after online session]  The above proposal was basically agreed. See chairman’s note for agreement.  FL thinks that we need to firm up on what symbol-level OCC and slot-level OCC precisely mean. These (especially “slot-level”) are a bit vague at the moment as they allow companies to propose a specific scheme within the overall umbrella of symbol-OCC or slot-OCC. |
| Nokia, NSB | OK.  We do not think there should be multiple schemes, to limit the complexity of IoT UE.  If for down-selection, we are ok to include symbol-level and slot-level scheme in the list. |
| TCL | We are fine with the proposal.  We think the OCC scheme for the single-tone with 3.75kHz and 15kHz should have a unified solution. |
| FL | The following agreement was made in the online session on Monday 20 May:  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. |

Some companies [Huawei, Samsung, vivo, CATT, Xiaomi, Sharp, Nokia, Oppo] propose that there should be a unified design between the single-tone and multi-tone schemes and / or between 15kHz and 3.75kHz single-tone schemes. [Ericsson] propose that if both 3.75kHz and 15kHz tone spacings are supported then symbol-level is supported, but if only 15kHz tone spacing is supported then slot-level is supported

**[FL1] Proposal 4.3-2: For 15kHz single-tone OCC, RAN1 supports symbol-level OCC. Other OCC schemes are not pursued for 15kHz single-tone OCC.**

Companies are invited to comment on proposal 4.3-2. Companies could comment on:

* whether they support the proposal
* if there is a different scheme that they would propose as a single scheme
* whether they want to support multiple schemes and have the eNB configure one of the schemes
* whether they are OK to perform some down-selection at this time, but are not yet ready to down-select to a single scheme
* whether a unified scheme (with 3.75kHz and / or multi-tone) is supported

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Ericsson | If NPUSCH Format 1 single-tone is intended to be supported for both 15 kHz and 3.75 kHz SCS, then Proposal 4.3-2 is ok aiming for pursuing a common design. |
| Lenovo | See comment above |
| LGE | In our understanding, the performance difference between symbol-level OCC and slot-level OCC for single-tone NPUSCH with 3.75kHz SCS is less than 0.5dB.  To minimize workload, our 1st preference is to support only slot-level OCC.  To bypass 200MHz frequency offset that will affect to OCC orthogonality, it can be considered that eNB estimates the CFO for the reived NPUSCH without OCC, then the eNB indicates applying OCC to NPUSCH when the estimated CFO is less than a certain threshold. |
| Spreadtrum | We think Proposal 4.3-2 should be combined with Proposal 4.3-1, whether 3.75 kHz or 15kHz of single tone should be support.   |  | | --- | | **Proposal 4.3-X: For 3.75kHz and 15kHz single-tone OCC, RAN1 supports symbol-level OCC. Other OCC schemes are not pursued for 15kHz single-tone OCC.** | |
| FL | LGE> Agree with your observations, as per the previous proposal.  Proposal 4.3-1v2 now refers to both 3.75 and 15kHz and so should address issues about unity of scheme for 3.75, 15kHz. |
| Nokia, NSB | OK.  We do not think there should be multiple schemes, to limit the complexity of IoT UE.  If for down-selection, we are ok to include symbol-level and slot-level scheme in the list.  We also prefer unified scheme between 3.75kHz and 15kHz SCS. |
| TCL | We are fine with the proposal.  We think the OCC scheme for the single-tone with 3.75kHz and 15kHz should have a unified solution. |

While the performance evaluations in section 4.2 have shown that OCC schemes can work for multi-tone with little performance degradation compared to the baseline no-OCC case, some companies [vivo, Interdigital, Ericsson, Mediatek] suggest that single-tone schemes are prioritised over multi-tone schemes. Some of the arguments include:

* single-tone operation is supported in NB-IoT for the sake of UL capacity anyway. A network would initially choose single-tone non-OCC operation in order to increases capacity and would only then use an OCC scheme if capacity needed to be further improved
* single-tone operation is appropriate for the link budgets observed in NTN deployments

Other companies [Huawei, Samsung, vivo, CATT, CMCC, Xiaomi, Sharp, Nokia, Oppo] propose that there should be a unified scheme for single-tone and multi-tone. It is not clear that this would reduce the workload as both single-tone and multi-tone schemes would still have to be specified. Furthermore, the choice of scheme for single-tone might be impacted by considerations on multi-tone, where the multi-tone scheme is less suitable for deployment anyway. It would hence seem preferable to priortise support of single-tone. Decisions can be taken on the basis of single-tone considerations and these can then be applied to multi-tone at a future data if there is time and will.

Hence the following proposal is made.

**[FL1][FL2][FL3] Proposal 4.3-3: RAN1 prioritises support of single-tone OCC over multi-tone OCC.**

Companies are invited to comment on proposal 4.3-3. Companies could comment on:

* whether they support the proposal
* whether there are cases where a network would choose to use multi-tone OCC in preference to single-tone
* if there were a unified scheme, would design decisions be primarily motivated by single-tone considerations?
* any other suggestions to manage the workload

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Ericsson | Ok with Proposal 4.3-3, because in addition to decide whether to support NPUSCH Format 1 single-tone for 15 kHz SCS, or 3.75 kHz SCS or both, RAN1 still needs to discuss the DMRS design. |
| Lenovo | Hope to have discussion in the same priority for the two cases since multi-tone OCC have the benefit on uplink capacity enhancement. |
| Nokia, NSB | No.  As anyway the capacity issue for IoT NTN will be more serious than the issue in NTN, we think UL capacity enhancement for IoT NTN have more stronger requirement and should be supported for all cases in IoT NTN, i.e. both single-tone and multi-tone. |
| vivo | Support.  There may be cases where a network would choose to use multi-tone OCC, e.g. larger TBS for high data rate or delay-sensitive service. |
| TCL | We are fine with the study of the two case for improving UL capacity in IoT NTN. |
| FL | We discussed this in the offline session in the morning of Tuesday 21 May:  **For NPUSCH format 1, RAN1 prioritises support (the design IDC) of single-tone OCC over multi-tone OCC.**   * **RAN1 Strives to specify MT based on the same techniques as ST – QC** * **Should we prioritise 3.75 over 15? QC** * **What does prioritisation mean? Samsung**   + **Decisions made on ST rather than MT – my response** * **Discussion on whether a scheduler would schedule multi-tone rather than single-tone** * **Should we agree to support both schemes and then agree about priorities? Lenovo** * **MT for high SNR UEs. Ericsson** * **In NTN scenarios, like GEO, only ST would be used. Also OK to do MT. CMCC**   Decoding these raw notes, I think a proposal could be:  **[FL3] Proposal 4.3-3v2**  **For NPUSCH format 1, RAN1 prioritises the design of single-tone OCC over multi-tone OCC.**  I think we should avoid saying “strive to specify MT using the same techniques as ST” as that wording seems to presuppose that MT will be supported. I think there is some doubt from companies about whether MT provides capacity enhancement over ST.  It would be helpful if companies could try to evaluate in RAN1#118 contributions if there are cases where MT with OCC provides a capacity gain over ST without OCC. I suspect this would help convince companies that we should treat MT and ST with the same priority.  I think the wording of **Proposal 4.3-3v2** doesn’t say anything about whether MT is supported or not. It doesn’t close doors.  [*note on terminology: ST = single-tone, MT = multi-tone*] |
|  |  |

## Evaluation results on DMRS

A performance comparison of TDM and CDM schemes for DMRS was considered by Huawei, ZTE and Oppo for single-tone OCC. Note that for multi-tone OCC, DMRS for different UEs in an OCC pairing could be separated on the basis of cyclic shift rather than on the basis of TDM / CDM.

The results for 15kHz single-tone operation are shown in Table 5 below. This table shows the degradation of CDM over TDM. Note that the results from Huawei show the opposite – that CDM performs worse than TDM.

Table 5 – DMRS: CDM performance gain over TDM

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **OCC2** |  | **OCC4** |  |
| **Company** | **Symbol** | **Slot** | **Symbol** | **Slot** |
| **Huawei** | -3.32 | -3.28 | -4.70 | -6.01 |
| **ZTE** | 1.2 | 1.2 | 1.6 | 1.6 |
| **Oppo** | 1.5 | 1.8 |  |  |

The relative performance of CDM and TDM for DMRS may depend on:

* Assumed DMRS structure (although the structures used in all of the simulations above seem to be similar)
* Decoding algorithm (this is not explicitly laid out in contributions)

The TDM and CDM structures used by Huawei, ZTE and Oppo in the simulations are summarised in the following figure (from Oppo R1-2404864):



Figure 1 - CDM and TDM DMRS structures (from Oppo R1-2404864)

Given the divergence of results, it is difficult to draw conclusions on whether CDM or TDM should be supported for DMRS based on evlauation results. Companies are encouraged to further analyse the perormance of TDM and CDM for DMRS are bring further results to RAN1#118.

The table below allows companies who provided simulation results to comment on the FL’s summary table in Table 5.

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

## DMRS

The following views on DMRS were submitted in input documents to RAN1#117:

* **Comparison of CDM and TDM DMRS**
  + TDM DMRS performance better than CDM performance [Huawei]
  + TDM DMRS performance worse than CDM performance [ZTE, Oppo]
    - TDM DMRS performance is worse due to lower DMRS density [ZTE]
    - TDM DMRS causes non-contiguous UL transmissions and may lead to phase discontinuity [LGE]
    - TDM DMRS creates large gap for measuring CFO (a bad thing) [LGE]
  + CDM allows OCC operation to apply to both DMRS and data [CATT]
  + Preferred DMRS scheme:
    - CDM: Spreadtrum (?), ZTE, LGE, CATT, NEC (?), ETRI, Oppo, Qualcomm (?)
    - TDM: Huawei, Lenovo,
* **Location of DMRS symbols**
  + TDM of DMRS (in current locations) can only support the OCC multiplexing of 2UEs for 3.75kHz single-tone [Spreadtrum]
  + DMRS locations modified to support pull-in range and to maintain DMRS overhead, i.e. adopt a cluster structure [NEC, Qualcomm]
  + Increase number of DMRS symbols [LGE]
  + Guard period location in 3.75kHz slot format needs to keep the same location as legacy, irrespective of spreading [Ericsson]
  + Remapping of DMRS symbols to new locations may incur interference to DMRS from legacy UEs [Lenovo]
* **Multi-tone DMRS**
  + Multi-tone DMRS can be differentiated based on cyclic-shifts [Huawei, CMCC, Nokia]
* **Others**
  + Additional seed for DMRS random number generation [LGE]

**CDM vs TDM**

It is difficult to decide between CDM and TDM of DMRS based on evaluation results alone as the evaluation results differ. Maybe we could make progress on the basis that:

* Some evaluation results show CDM performance is better than TDM performance.
* There is a higher DMRS density when CDM is applied. When DMRS is applied in two symbols and OCC-ed, isn’t there twice as much DMRS power than for TDM case where some DMRS symbols are dropped?
* TDM causes non-contiguous transmissions, which might affect the overall performance of OCC (if there is a loss of phase coherency either side of the DMRS).
* A majority of companies support CDM. However, we should make decisions based on technical merits rather than votes.

**[FL1][FL2][FL3] Proposal 4.5-1: For single-tone transmissions, a CDM DMRS scheme is supported.**

Companies are invited to comment on proposal 4.5-1. Companies could comment on:

* Whether you support the proposal
* Is there better wording?
* Is there a fatal flaw in the CDM scheme that TDM doesn’t have

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Ericsson | We should clarify that the proposal is for NPUSCH Format 1 single-tone with 3.75 kHz SCS. We also need clarify what is going to happen with the “Guard Period” which is part of the slot format for 3.75 kHz SCS, for which we should keep its location as per legacy before and after the OCC spreading. We can be ok upon adding those clarifications. |
| Lenovo | If symbol-level based OCC scheme is adopted for single tone, DMRS scheme should be enhanced. We are not ready to accept the CDM DMRS scheme (although we are open with either TDM or CDM), since we don’t have in mind that what kind of CDM DMRS scheme is on the table (how about DMRS density in each slot? New DMRS symbol position for slot? ). Can we list some details on the solution for better understanding?  If slot-level based/repetition scheme-based OCC scheme is adopted for single tone, we are OK that the DMRS should be CDM OCC accordingly. |
| FL | It sounds like we need to understand the DMRS schemes on the table better. My understanding is that we have the following schemes:  Huawei, ZTE, Oppo:    Ericsson:    Qualcomm    Are there any other DMRS locations being considered?  Lenovo> My understanding is that the DMRS densities per slot vary, as per the figures above, but the average DMRS density (over a long period of time) is the same as legacy |
| Nokia, NSB | Not support.  We think firstly it should be discussed whether legacy DMRS mapping can be reused but no CDM and no TDM, as legacy DMRS can also provide orthogonality in channel estimation and both of CDM/TDM may impact system performance. |
| vivo | In our understanding, at least 2 slots are required to perform TDMed DMRS or CDMed DMRS, and if TDMed DMRS is applied, slots without DMRS would depend on the channel estimation from the slots with DMRS, which would result in performance degradation if frequency error exists. Thus, we slightly prefer CDM DMRS scheme. |
| TCL | For TDM DMRS, the time domain location of DMRS for different UEs will be different and the destiny of TDM DMRS will decrease as the increase of the number of multiplexed UE, which will impact the accuracy of the channel estimation. Thus, we support CDM DMRS scheme. |
| ZTE | Support.  With same overall DMRS overhead, CDM has better performance than TDM, while both scheme can offer orthogonality among UEs, so we prefer CDM.  In addition, same scheme is recommended to be reused for multi-tone. The same DMRS design is critical to reduce implementation complexity and spec effort. |

**Location of DMRS symbols**

As described in the company views above, there are potentially good reasons for supporting DMRS in different symbol locations compared to those used in Rel-18. These reasons include:

* Support pull-in range for operations with 200Hz CFO while maintaining DMRS overhead
* DMRS locations would change as part of the spreading process anyway

These issue about spreading changing the DMRS locations is considered by Ericsson (R1-2404534):



Figure 5a: Example of legacy DMRS distributions using the legacy slot format for NPUSCH Format 1 with 15 kHz SCS before the OCC spreading.



Figure 5b: Example of legacy DMRS distributions using the legacy slot format for NPUSCH Format 1 with 15 kHz SCS after the OCC spreading.

A DMRS structure to support a bigger pull-in range while maintaining overhead is illustrated by Qualcomm in R1-2405175.

A blue squares on a white background

Description automatically generated

The default assumption would be that OCC DMRS locations are the same as Rel-18. The FL view is that RAN1 should at least consider new OCC DMRS locations. Having the visibility that this is a possibility might help to converge evaluation results.

**[FL1] Proposal 4.5-2: For single-tone OCC multiplexing, RAN1 studies:**

* **Rel-18 mapping of DMRS to symbols in the slot structure**
* **Alternative mappings of DMRS to symbols in the slot structure**

Companies are invited to comment on proposal 4.5-2. Companies could comment on:

* Whether you support the proposal
* Is there better wording?
* Is there a better proposal that would allow us to investigate how to achieve the goal of a DMRS structure that performs acceptably based on a 200Hz CFO?

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Ericsson | We think the proposal should differentiate between 15 kHz SCS and 3.75 kHz SCS. For 15 kHz we believe the legacy DRMS mapping can be re-used, whereas for 3.75 kHz SCS an alternative DMRS mapping needs to be discussed. |
| LGE | Depending on whether symbol-level OCC is supported or not, alternative mapping of DMRS may not need to be discussed. We can add “at least for symbol-level OCC” to the 2nd bullet. |
| FL [FL2][FL3] | Maybe we could have two proposals:  **Proposal 4.5-2v2:**   * **For the mapping of DMRS to symbols in the time domain:**   + **For 15kHz single-tone, RAN1 strives to reuse the Rel-18 mapping of DMRS to symbols in the slot structure**   + **For 3.75kHz single-tone, RAN1 studies**     - **Rel-18 mapping of DMRS to symbols**     - **Alternative mappings of DMRS to symbols** |
| Nokia, NSB | OK for study.  We think that if legacy DMRS mapping can work, then no need to have modification that increase on complexity of UE implementation. |
| vivo | OK for study. But we also think additional dmrs symbol is not preferred |
| TCL | We are fine with the proposal. |
| ZTE | Generally OK with the spirit, but we have similar view that we should strive to reuse the legacy mapping, otherwise, there will be backward compatibility issues. So we suggest the following revision on the proposal:  **Proposal 4.5-2v2:**   * **For the mapping of DMRS to symbols in the time domain, for 15kHz and 3.75kHz single-tone, RAN1 strives to reuse the Rel-18 mapping of DMRS to symbols in the slot structure** |

## Signalling and configuration

The following issues related to configuration and signalling of OCC were considered:

* Configuration of basic unit length of OCC
  + Can be configured by a value X [Len]
* Signalling of OCC sequence
  + DCI, semi-static (RRC) or based on C-RNTI

As per RAN1#116 and RAN1#116bis, it is considered that these signalling issues can be considered at a future meeting.

## UL segments

The following issues on UL segments were considered by companies, as for previous meetings:

* Segments
  + Consider the effects of UL segments on OCC operation
    - There will be loss of phase continuity between segments
    - If OCC spans a dropped symbol within a segment gap, the whole segment is dropped, otherwise there will be a loss of orthogonality from a partial OCC unit

At previous meetings, companies preferred to decide on the basic scheme before considering UL segments. FL considers that this is still the situation. Hence, FL suggests that we consider issues related to UL segments in a future meeting.

## Compatibility with other features

The following issues on compatibility with other features were considered in company contributions:

* Other features (other than connected mode dynamic grant) with which NPUSCH OCC should work
  + IDLE / INACTIVE (including EDT) [Xiaomi]
    - Xiaomi are unsure whether OCC applies to these cases in the current WID
  + EDT [QC, TCL]
  + PUR [QC, TCL]
  + RACH-less EDT (Rel-19) [QC]
* Compatibility and coexistence with legacy UEs [Nokia]

It seems like OCC multiplexing for NPUSCH format 1 should operate with the following schemes:

* + Connected mode dynamic grant
  + EDT
  + PUR
  + RACH-less EDT (Rel-19)

OCC multiplexing for NPUSCH format 1 should coexist with legacy UEs.

We should probably decide on the basic OCC multiplexing scheme before considering the features that OCC is going to need to operate with. RAN1 is going to have to consider the compatibility and coexistence with legacy UEs in any case. FL hence proposes that we consider the basic OCC schemes before considering how to apply OCC to the feature list above.

# NPRACH

## Overall summary of issues raised in Tdocs

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

NPRACH

* Views on schemes:
  + Intra-symbol group OCC
    - Spec impact related to CP support [Spreadtrum, Apple, CATT, Xiaomi, Sharp, Mediatek]
    - Lack of CP would cause interference [HW, TCL]
    - New PRACH format would be required [CATT]
    - OCC2 can fit into this scheme including 2 CP (and 2xOOC2) [NEC]
    - OCC3 has only 0.18dB degradation compared to no OCC [Qualcomm]
  + Inter-symbol group(s) OCC
    - More susceptible to CFO than intra-symbol [Spreadtrum, Qualcomm]
    - Less susceptible to CFO than repetition level [IDC]
    - Can phase continuity and power continuity be maintained across frequency hops? [HW]
    - Big hops / little hops
      * Apply only to big freq hops as small frequency hops are used for CFO estimation [ZTE]
      * Consider separate potential schemes for big hops and little hops [Mediatek]
    - Change frequency hopping mechanism [NEC]
    - OCC3 has a 1.2dB degradation compared to no OCC [HW]
  + Inter-repetition OCC
    - Can phase continuity and power continuity be maintained across frequency hops? [HW]
    - CFO is too large to support this [ZTE, Xiaomi, TCL]
    - Change frequency hopping mechanism [NEC]
  + Joint schemes
    - Consider how to apply if more than one scheme is configured [Sharp]
      * FL: shouldn’t the eNB only be able to configure one scheme?
* Do not support NPRACH OCC
  + Not bottleneck [vivo, CATT, HW]
    - Would be the bottleneck if NPUSCH OCC is supported, hence support [Nokia]
  + Too much spec impact and / or workload [Samsung, vivo, CATT, HW, Ericsson]
  + Performance degradation [HW, Ericsson]
    - False preamble detection rate increases [Ericsson]
  + Compatibility with legacy UEs if direct spreading in time domain is applied [Ericsson]
* OCC sequences
  + Applicable OCC sequences (Walsh vs DFT etc) depends on the scheme considered [Apple]
    - Some schemes only allow length 3 or length 5 DFT sequences [Apple]
    - Length 3 sequences [QC]
* Configuration of sequences
  + SIB [Spreadtrum]
  + Can be configured by a value X [Len]
    - This would mean that the standard would have to specify how the multiple different approaches would work and then the network would have to configure one of them
* Synchronisation accuracy
  + Study whether to tighten synchronisation accuracy requirements to allow OCC [NEC]
* Codebook index hopping [NEC]
  + Issue should be studied, as it was for NR PUCCH [NEC]
* Partitioning [NEC]
  + Will OCC support NPRACH partitioning to indicate single-tone / multi-tone Msg3?
  + Separate NPRACH resource space for OCC [Apple, IDC, Ericsson, ETRI]
  + Try to support legacy UEs and OCC UEs in the same resource [QC]
* Selection probability of anchor vs non-anchor carrier [NEC]
  + Needs enhancement [NEC]
* RAR / RAPID impact
  + Will have to account for OCC used [LGE, Spreadtrum, Ericsson, TCL]
  + Separate RA-RNTI for OCC since legacy UEs will not understand the RAPID [LGE, Spreadtrum]
* Pairing
  + OK as there is not significant RSRP change within an NTN cell [Spreadtrum]
  + PRACH resources to use depend on measured RSRP in order to get power balance [LGE]
* Scheme compatibility. OCC for NPRACH should work with the following features:
  + Initial access
  + EDT
  + PDCCH order
  + Connected mode CBRA

## Evaluation of NPRACH OCC schemes

NPRACH OCC performance was evaluated by Huawei and Qualcomm.

Huawei provided the following evaluation results for inter-symbol group OCC:



Figure 2 – Inter-symbol group NPRACH OCC performance from Huawei R1-2403941

Qualcomm provided the following results for intra-symbol group OCC:

A graph of a function

Description automatically generated with medium confidence

Figure 2 – Intra-symbol group NPRACH OCC performance from Qualcomm R1-2405175

The y-axes of both of these sets of results is considered to be equivalent (for HW, an NPRACH received with an excessive timing error would be considered to be missed).

The performance degradation of the schemes for OCC3 is:

* Intra-symbol group OCC (Qualcomm): 0.18dB
* Inter-symbol group OCC (HW): 1.2dB

The table below allows companies who provided simulation results to comment on the FL’s observations above.

|  |  |
| --- | --- |
| **Company** | **Comment** |
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**[FL2][FL3] Observation 5.2-1: The performance of the NPRACH OCC schemes degrades as the time span of the schemes increases (intra-symbol group to inter-symbol group).**

Companies are invited to comment on observation 5.2-1. Note that there is no intention to reach an agreement on this observation in the meeting.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Spreadtrum | There might be some misunderstanding of Huawei’s evaluation. In R1-2403941, LLS results is for intra-symbol group OCC, not inter-symbol group OCC. The result shows that intra-symbol OCC would bring significant performance degradation.  We think observation 5.2-1 and 5.2-2 need to be revised. |
| LGE | I have some comments on the first evaluation results. When we see the required SNR for a single UE without OCC case, the required SNR seems too high to support IoT NTN even without applying OCC. To be specific, it seems like that even without OCC, IoT NTN may not work properly. So, in this point of view, we’re not so sure that it is a typical scenario for IoT NTN. It would be better to focus on the typical scenario for IoT NTN to make some observation for NPRACH with or without OCC. |
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**[FL2][FL3] Observation 5.2-2: Either intra-symbol group OCC or inter-symbol group OCC would provide an UL capacity gain for NPRACH.**

Companies are invited to comment on observation 5.2-2. Note that there is no intention to reach an agreement on this observation in the meeting.

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| **Company** | **Comment** |
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## NPRACH OCC schemes

The overall view on NPRACH OCC schemes is:

* + Intra-symbol group OCC
    - Spec impact related to CP support [Spreadtrum, Apple, CATT, Xiaomi, Sharp, Mediatek]
    - Lack of CP would cause interference [HW, TCL]
    - New PRACH format would be required [CATT]
    - OCC2 can fit into this scheme including 2 CP (and 2xOOC2) [NEC]
    - OCC3 has only 0.18dB degradation compared to no OCC [Qualcomm]
  + Inter-symbol group(s) OCC
    - More susceptible to CFO than intra-symbol [Spreadtrum, Qualcomm]
    - Less susceptible to CFO than repetition level [IDC]
    - Can phase continuity and power continuity be maintained across frequency hops? [HW]
    - Big hops / little hops
      * Apply only to big freq hops as small frequency hops are used for CFO estimation [ZTE]
      * Consider separate potential schemes for big hops and little hops [Mediatek]
    - Change frequency hopping mechanism [NEC]
    - OCC3 has a 1.2dB degradation compared to no OCC [HW]
  + Inter-repetition OCC
    - Can phase continuity and power continuity be maintained across frequency hops? [HW]
    - CFO is too large to support this [ZTE, Xiaomi, TCL]
    - Change frequency hopping mechanism [NEC]
  + Joint schemes
    - Consider how to apply if more than one scheme is configured [Sharp]
      * FL: shouldn’t the eNB only be able to configure one scheme?

There does not seem to be much enthusiasm for inter-repetition OCC for NPRACH. No companies provided evaluation results of repetition-level OCC. There are concerns with how CFO will impact inter-repetition OCC. There are also other concerns. Hence it is proposed that inter-repetition OCC for NPRACH is not pursued.

**[FL2][FL3] Proposal 5.3-1: Inter-repetition OCC for NPRACH is not pursued in RAN1.**

Companies are invited to comment on proposal 4.3-1. Companies could comment on:

* whether they support the proposal
* whether they are OK to perform some down-selection at this time, but this is not the down-selection that they would prefer

|  |  |
| --- | --- |
| **Company** | **Comment** |
| vivo | agree |
| TCL | OK with the proposal. |
| ZTE | Agree |
| LGE | OK |
|  |  |

Many companies have concerns on how the CP would be handled for intra-symbol group NPRACH, but it would seem to be possible to address these issues since the company that simulated intra-symbol group OCC successfully managed to simulate this scheme: it seems like CP is not an insurmountable obstacle. In terms of a new NPRACH format being required, it would seem that the NPUSCH OCC schemes will also require a new resource mapping. Hence the requirement to support a new NPRACH format would not seem to be a showstopper.

**[FL2][FL3] Proposal 5.3-2: For the study of intra-symbol group NPRACH OCC, RAN1 further considers how CP can be accounted for in the NPRACH structure.**

Companies are invited to comment on proposal 5.3-2. Companies could comment on:

* whether they support the proposal
* clarify what the role of CP is within the intra-symbol group OCC

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| **Company** | **Comment** |
| TCL | Ok with the proposal. Due to the lack of CP between symbols after spreading, the inter-symbol interference will happen. The straightforward way is to insert the CP among the symbols, however it will bring the great influence on the spec. So we are support the study of more effective ways. |
| ZTE | Fine to study. |
| LGE | OK |
|  |  |
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For inter-symbol group NPRACH OCC, there seems to be issue about how OCC interacts with frequency hopping, including whether OCC is only applied to the big hops within the NPRACH frequency hopping scheme or to both the big and little frequency hops. There is also an issue of whether phase and power continuity can be maintained across frequency hops.

**[FL2][FL3] Proposal 5.3-3: For the study of inter-symbol group NPRACH OCC, companies should indicate how OCC is applied to the large and small frequency hops .**

Companies are invited to comment on proposal 5.3-3. Companies could comment on:

* whether they support the proposal
* whether there is better wording
* their understanding of how inter-symbol group OCC can allow estimation of time and frequency offset by differential operation

|  |  |
| --- | --- |
| **Company** | **Comment** |
| ZTE | Fine to study.  For inter-symbol group OCC, the same OCC codeword can be applied for 2 symbol groups, so that the timing error can be estimated by the adjacent symbol groups with small frequency hops, then different OCC codewords can be applied across 2 symbol groups for UE multiplexing. |
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## Whether OCC should apply to NPRACH

The following issues were raised regarding whether OCC should apply to NPRACH:

* Do not support NPRACH OCC
  + Not bottleneck [vivo, CATT, HW]
    - Would be the bottleneck if NPUSCH OCC is supported, hence support [Nokia]
  + Too much spec impact and / or workload [Samsung, vivo, CATT, HW, Ericsson]
  + Performance degradation [HW, Ericsson]
    - False preamble detection rate increases [Ericsson]
  + Compatibility with legacy UEs if direct spreading in time domain is applied [Ericsson]

While there many negative comments in the above list, there are likely to be companies who think that this issue does not even need to be debated as NPRACH support is mentioned in the WID. The discussion in the FLS in RAN1#116bis Changsha was inconclusive in terms of whether NPRACH should support OCC or not and it is expected that this situation will not change in this meeting.

Maybe we could consider prioritisation of study of OCC for NPUSCH over OCC for NPRACH, given that NPUSCH is more likely to the bottleneck than NRACH in terms for UL capacity.

**[FL2][FL3] Proposal 5.4-1: OCC for NPUSCH is treated with higher priority than OCC for NPRACH.**

Companies are invited to comment on proposal 5.4-1. Companies could comment on:

* whether they support the proposal
* whether there is a better way to manage the workload

|  |  |
| --- | --- |
| **Company** | **Comment** |
| vivo | Agree |
| ZTE | They can be studied in parallel, the discussion can be contribution driven, no need for any prioritization. |
| LGE | We share similar views with ZTE. |
|  |  |
|  |  |

## RAR and RAPID

The following issues were raised regarding the random access response:

* RAR / RAPID impact
  + Will have to account for OCC used [LGE, Spreadtrum, Ericsson, TCL]
  + Separate RA-RNTI for OCC since legacy UEs will not understand the RAPID [LGE, Spreadtrum]

There was general agreement in previous meetings that this issue is a valid one and could be considered in future meetings, once progress has been made on the basic NPRACH OCC multiplexing scheme. This would seem to be the status at this meeting too.

## Partitioning

The following issues were raised regarding partitioning of the NPRACH resource:

* Partitioning [NEC]
  + Will OCC support NPRACH partitioning to indicate single-tone / multi-tone Msg3?
  + Separate NPRACH resource space for OCC [Apple, IDC, Ericsson, ETRI]
  + Try to support legacy UEs and OCC UEs in the same resource [QC]

It would seem that partitioning would only be required if legacy UEs cannot be supported within the NPRACH OCC scheme. There are proposals (e.g. from QC – that one of the OCC codewords is ‘111111’ and can be used by the legacy UE) that would not require NPRACH partitioning. Hence, it would seem to be premature to support NPRACH partitioning until we have a firmer idea on the NPRACH OCC scheme itself.

## Compatibility with other features

The following issues on compatibility with other features were considered in company contributions:

* Scheme compatibility. OCC for NPRACH should work with the following features: [QC]
  + Initial access
  + EDT
  + PDCCH order
  + Connected mode CBRA

It seems like OCC multiplexing for NPRACH format 1 should operate with the following schemes:

* + Initial access
  + EDT
  + PDCCH order
  + Connected mode CBRA

OCC multiplexing for NPRACH format 1 should coexist with legacy UEs, possibly through PRACH partitioning or natively. FL suggests that these issues can be considered at a future meeting once the basic OCC scheme for NPRACH has been decided.

## Configuration

The following issues on configuration were considered in company contributions:

* Configuration of sequences
  + SIB [Spreadtrum]
  + Can be configured by a value X [Len]
    - This would mean that the standard would have to specify how the multiple different approaches would work and then the network would have to configure one of them

It is clear that at some stage, we will have to address configuration of OCC. Until we know what NPRACH OCC scheme is going to be supported, it would seem to be too early to consider this configuration issue.

# Monday 20 May: online proposals for discussion

**Proposal 4.3-1v2:**

**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.**

**Proposal 4.3-3:**

**RAN1 prioritises support of single-tone OCC over multi-tone OCC.**

**Proposal 4.5-2v2:**

* **For the mapping of DMRS to symbols in the time domain:**
  + **For 15kHz single-tone, RAN1 strives to reuse the Rel-18 mapping of DMRS to symbols in the slot structure**
  + **For 3.75kHz single-tone, RAN1 studies**
    - **Rel-18 mapping of DMRS to symbols**
    - **Alternative mappings of DMRS to symbols**

# Conclusions

This document is the feature lead summary for IoT-NTN in RAN1#117. It contains the FLS discussion and lists the proposals that were considered in online sessions.

# References

[1] RP-234070 New WID: Non-Terrestrial Networks (NTN) for Internet of Things (IoT) Phase 3.

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

[3] R1-2403719 FL Summary #2 for IoT-NTN. Moderator (Sony). RAN1#116bis, Changsha. April 2024.

R1-2403941 Discussion on UL capacity enhancements for IoT NTN Huawei, HiSilicon

R1-2404044 Discussion on IoT-NTN uplink capacity/throughput enhancement Spreadtrum Communications

R1-2404135 Discussion on uplink capacity/throughput enhancement for IoT-NTN Samsung

R1-2404197 Discussion on IoT-NTN uplink capacity enhancement vivo

R1-2404217 Discussion on UL capacity enhancement for IoT NTN ZTE

R1-2404264 IoT-NTN uplink capacity/throughput enhancement InterDigital, Inc.

R1-2404310 Discussion on IoT-NTN Uplink Capacity Enhancement Apple

R1-2404326 Discussion on IoT-NTN uplink capacity/throughput enhancement LG Electronics

R1-2404393 Discussion on UL capacity enhancement for IoT NTN CATT

R1-2404442 Discussion on uplink capacity enhancement for IoT NTN Lenovo

R1-2404474 Discussion on the IoT -NTN uplink capacity/throughput enhancements CMCC

R1-2404534 On uplink capacity enhancements for IoT-NTN Ericsson

R1-2404610 Discussion on IoT-NTN uplink capacity enhancement Xiaomi

R1-2404672 IoT-NTN uplink capacity/throughput enhancement NEC

R1-2404695 IoT NTN OCC multiplexing methods for NPUSCH and NPRACH Sharp

R1-2404742 IoT-NTN uplink capacity enhancement Nokia, Nokia Shanghai Bell

R1-2404787 Discussion on uplink capacity/throughput enhancement for IoT NTN ETRI

R1-2404864 Discussion on IoT-NTN uplink capacity/throughput enhancement OPPO

R1-2405093 Discussion on IoT-NTN uplink capacity and throughput MediaTek Inc.

R1-2405175 IOT-NTN uplink capacity/throughput enhancement Qualcomm Incorporated

R1-2405178 Discussion on the IoT-NTN uplink capacity/throughput enhancements TCL