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**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].

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:

* **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**. Is it sufficient to support single-tone?
* **Maximum number of UEs that can be OCC-ed**: 2 or 4
* **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?
* **Downlink impacts**. Identify changes that are required to DL procedures.

**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?

There is enough to consider for NPUSCH in the first version of the FLS, so the NPRACH section will be updated once NPUSCH has been discussed.

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.*
* If no update is uploaded in 30 minutes, other companies can ignore the checkout file.

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 [FL1].

The table below provides a list of points of contact within companies for this WI. Contact details from RAN1#117 Fukuoka use a blue font. Please feel free to update your contact details and convert into a black font.

**[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]
 |

# Previous agreements

The following agreements were made in RAN1#116 Athens:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| Agreement#116-IoT-NTN #1For 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-2The 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-CThe channels from different UE are independent. |
| Frequency error | Uniform random selection from [-0.1 ppm, +0.1 ppm] for all UEsVariation of frequency error is negligible. |
| Timing error | Uniform random selection from [-97Ts, +97Ts] for all UEsTiming 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 3.75kHzOS#4 per slot for 15kHzFor OCC evaluations:Up to proponent | For baseline evaluations:OS#4 per slot for 15kHzFor OCC evaluations:Up to proponent |
| Number of resource unit ($N\_{RU}$)  | Up to proponent | Up to proponent |
| Modulation order $(Q\_{m})$ | Up to proponent | Up to proponent |
| TBS ($I\_{TBS}$) | Up to proponent | Up to proponent |
| Number of repetitions ($N\_{rep}$) | 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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| AgreementFor the NPUSCH evaluation assumptions, update the DMRS configuration, as follows:

|  |  |  |
| --- | --- | --- |
| DMRS configuration  | For baseline evaluations:OS#4 per slot for 3.75kHzOS#3 per slot for 15kHzFor OCC evaluations:Up to proponent | For baseline evaluations:OS#3 per slot for 15kHzFor OCC evaluations:Up to proponent |

AgreementAt least the following NPRACH OCC schemes are considered by RAN1 for study:* Intra-symbol group OCC
* Inter-symbol group(s) OCC
* Inter-repetition OCC

AgreementThe study of OCC for NPRACH does not consider NPRACH format 2.AgreementThe 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-CThe channels from different UE are independent. |
|  | Frequency error | Uniform random selection from [-0.1 ppm, +0.1 ppm] for all UEsVariation of frequency error is negligible. |
|  | Timing error | Uniform random selection from [-97Ts, +97Ts] for all UEsTiming drift 80us/s for LEO600 and 0 for GEO. |
|  | Power imbalance | Uniformly distributed between +Pimb and -Pimb for all UEsProponent 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 ($N\_{rep}$) | 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 |

AgreementOCC 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.AgreementFor OCC of NPUSCH format 1, RAN1 will not consider multiplexing more than 4 UEs.AgreementFor 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

AgreementFor 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 UEsVariation 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:

|  |
| --- |
| AgreementFor 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.AgreementInter-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

AgreementThe Rel-17 guard period locations and length for NB-IoT 3.75kHz UL slot are preserved when OCC is applied to NPUSCH format 1. |

# NPUSCH

## Overall summary of issues raised in Tdocs

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

**SCS**:

* 3.75kHz only
* 15 kHz only
* 3.75kHz and 15kHz: Viasat
	+ Both 3.75kHz and 15kHz deployed in networks [Viasat]

**Multi-tone support**:

* No: Ericsson, Samsung,Interdigital
	+ 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]
	+ Why wouldn’t you just do FDM of single-tone and achieve the same multiplexing gain? [Samsung][ZTE][Interdigital]
* Yes: Viasat, Lenovo, CMCC
	+ Newer satellites and HPUE make this viable [Viasat]
	+ Fast beam hopping favours multi-tone. Good to transmit data before the beam hops [Viasat]
	+ Minimal physical channel mapping impact [ZTE]
* Common time-domain solution with single-tone [Nok][Spreadtrum]
	+ Different schemes would increase eNB complexity
	+ Single-tone scheme is baseline, see whether it can be applied to multi-tone [Spreadtrum]

**OCC code type**

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

**3.75kHz OCC scheme**

* symbol: QC, Samsung, LGE, Spreadtrum
	+ High standards and implementation impacts [Apple][Samsung][CATT][OPPO][ZTE][CMCC]
	+ Better performance and standards impact of cross-slot and cross-symbol are similar [Samsung]
	+ Physical channel mapping rule needs to be changed [LGE][CATT][vivo][CMCC][Spreadtrum] [HW]
		- Consider impact on code rate [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]
* Slot: Apple, MTK, Sharp, CATT, OPPO, Interdigital, CMCC, HW
	+ Too much phase difference between UEs at maximum frequency offset [QC][Ericsson]
	+ Performance is similar to symbol-level
		- View [Apple]
		- Via Simulation results [CATT][HW]
			* OCC2 performance similar between slot, symbol [HW]
		- 1.1dB performance loss compared to baseline for OCC2 [CMCC]
	+ Simple spec changes [OPPO]
	+ Physical channel mapping rule needs to be changed [vivo][ZTE][CMCC] [Spreadtrum] [HW]
		- Consider impact on code rate [vivo]
		- Spread first [HW]
	+ Better performance [ZTE]
		- Higher tolerance to timing and frequency offset [ZTE]
* Nslot [ZTE]
	+ 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
	+ 4: QC, Apple, MTK, Sharp
		- SNR degradation up to 0.5dB [QC]
		- No throughput gain from OCC4 [HW]
		- 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]
	+ Effective multiplexing of users already supported by FDM-ing 4 UEs in 15kHz. No further capacity increase required [Xiaomi]

**15kHz OCC scheme**

* symbol: [Ericsson][Samsung]
	+ 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]
	+ Better performance and standards impact of cross-slot and cross-symbol are similar [Samsung]
	+ Physical channel mapping spec impact [OPPO][vivo][ZTE][CMCC] [Spreadtrum] [HW]
		- Consider impact on code rate [vivo]
		- Spread first [HW]
	+ Better performance [ZTE]
		- Higher tolerance to timing and frequency offset [ZTE]
* slot: [MTK][Sharp][LGE][CATT][OPPO][Interdigital][CMCC][Spreadtrum][HW]
	+ Minimal spec impact [OPPO]
	+ Simulation results show similar performance to symbol level [OPPO][CMCC][HW]
		- Note: 15kHz SCS has shorter time span than 3.75kHz SCS [CMCC]
	+ Physical channel mapping spec impact[vivo][ZTE][CMCC] [Spreadtrum][HW]
		- Consider impact on code rate [vivo]
		- Spread first [HW]
	+ Better performance [ZTE]
		- Higher tolerance to timing and frequency offset [ZTE]
	+ Allows common design with multi-tone [Spreadtrum]
* Nslot [ZTE]
	+ Minimum changes to physical channel mapping [ZTE]
	+ Performance impacted by frequency and timing offset [ZTE]
* Supported OCC lengths:
	+ 2: Apple, MTK, CATT, HW
	+ 4: Apple, MTK
		- OCC4 is about 2.5dB worse than OCC2 [CATT]
		- No throughput gain from OCC4 [HW]

**Multi-tone OCC scheme**

* symbol:
* slot / Nslot [CATT] [Interdigital][CMCC][HW]
	+ Minimum specification impact [CATT][CMCC][HW]
	+ Unified design with single-tone [CATT]
	+ Evaluation of OCC2 or OOC4 show large throughput gain and minimal SNR loss [ZTE]
	+ Slot level has better performance than RV-level [CMCC]
	+ Nslot performance degrades relative to slot performance due to longer time extent [HW]
* Repetition / RV-level
* Pre-DFT
	+ Different designs would be needed for different numbers of tones [CATT][vivo]
	+ Specification work would not be applicable to single-tone and hence generates more workload [OPPO]
* Time-domain approach common to single-tone [Xiaomi][OPPO][vivo]

**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
	+ Improved channel estimation at 15kHz [CATT]
	+ Minimal SNR loss in simulated results for OCC2 [QC][OPPO][ZTE]
		- Minimal SNR loss at 15kHz [HW]
		- Large SNR loss at 3.75kHz [HW]
	+ Create by spreading DMRS sequence and then applying OCC [QC]
	+ Create by masking legacy DMRS sequence with OCC sequence [vivo]
* TDM: Lenovo
	+ 0.2dB loss compared to CDM for OCC2 (CFO assumed): QC
	+ >1dB loss compared to CDM for OCC4 (CFO assumed): QC
	+ 2dB performance loss with OCC2 for Nslots: ZTE
	+ 15kHz
		- OCC2: 0.8dB performance loss [HW]
		- OCC4: 2.5dB performance loss [HW]
	+ 3.75kHz
		- OCC2: TDM is 4.5dB better than CDM due to multi-user interference with CDM with CFO
	+ 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]
	+ RAN1 discuss detailed candidates for TDM mapping [OPPO]
	+ Create by masking legacy DMRS sequence with 1/0 pattern [vivo]
	+ TDM mapping:
		- UE1 has two consecutive legacy DMRS followed by UE2 [CMCC]
			* Shorter timespan for a UE avoids wrap-around [CMCC][HW]
		- UE1 and UE2 have alternate legacy DMRS
* Depends on SCS [CATT]
	+ 15kHz:
		- CDM [CATT
			* Simulated performance is 6dB better than TDM [CATT]
		- TDM
	+ 3.75kHz
		- CDM
			* Loss of orthogonality means CDM doesn’t work [CATT]
				+ Note: probably depends on the DMRS pattern assumed [FL]
		- TDM [CATT]
* Multi-tone
	+ Cyclic shifts [CATT][HW]
		- Existing cyclic shift mechanism can be used [CATT][HW]
	+ OCC2:
		- TDM [CMCC]
	+ OCC4:
		- TDM + FDM (or + comb-like) [CMCC]

**DMRS sequence**

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

**3.75kHz DMRS pattern**



* Within cluster separation is x1 symbols, between cluster separation is x2 symbols [QC][Ericsson][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][Ericsson]
	+ X1 = 0 [LGE]
	+ Slot-level OCC cannot be used as the slots have different structures [HW]
* Study performance comparison of different patterns [ETRI]
* New DMRS pattern is required [QC][Ericsson][NEC][LGE]
* 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][Spreadtrum]
	+ Orthogonal DMRS are applied to UEs and eNB can distinguish [Spreadtrum]

**15kHz DMRS pattern**

* Legacy DMRS pattern used [Ericsson][NEC][LGE]
	+ No issues with pull-in range, so no need for a change [Ericsson]
* Study performance comparison of different patterns [ETRI]
* 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]
	+ Need clarification, assuming OCC is not applied to Msg3 [Xiaomi]
* PUR [QC][TCL]
* 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]
	+ Consider that there are different UL segment gap dropping rules (symbol, slot) [Spreadtrum]

**NPRACH collisions:**

* Align OCC scheme around NPRACH gaps [QC]
* Be aware of NPRACH collisions [Ericsson]
	+ NPRACH and UL gaps require postponements [Ericsson]

**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]
	+ Cross-symbol
	+ Cross slot
		- Increase $N\_{identical}^{NPUSH}$ to be the target OCC length [LGE]

**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]

**PAPR**

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

## 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, Samsung, LGE, Spreadtrum
	+ High standards and implementation impacts [Apple][Samsung][CATT][OPPO][ZTE][CMCC]
	+ Better performance and standards impact of cross-slot and cross-symbol are similar [Samsung]
	+ Physical channel mapping rule needs to be changed [LGE][CATT][vivo][CMCC][Spreadtrum] [HW]
		- Consider impact on code rate [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]
* Slot: Apple, MTK, Sharp, CATT, OPPO, Interdigital, CMCC, HW
	+ Too much phase difference between UEs at maximum frequency offset [QC][Ericsson]
	+ Performance is similar to symbol-level
		- View [Apple]
		- Via Simulation results [CATT][HW]
			* OCC2 performance similar between slot, symbol [HW]
		- 1.1dB performance loss compared to baseline for OCC2 [CMCC]
	+ Simple spec changes [OPPO]
	+ Physical channel mapping rule needs to be changed [vivo][ZTE][CMCC] [Spreadtrum] [HW]
		- Consider impact on code rate [vivo]
		- Spread first [HW]
	+ Better performance [ZTE]
		- Higher tolerance to timing and frequency offset [ZTE]
* Nslot [ZTE]
	+ 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
	+ 4: QC, Apple, MTK, Sharp
		- SNR degradation up to 0.5dB [QC]
		- No throughput gain from OCC4 [HW]
		- 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]
	+ Effective multiplexing of users already supported by FDM-ing 4 UEs in 15kHz. No further capacity increase required [Xiaomi]

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. Huawei compare the performance of a slot-based scheme with a symbol-based scheme and show the performance results in Figure 1 for OCC2. Huawei make the point that both the symbol-based and the slot-based schemes achieve the target performance at the target BLER. It is still apparent that the performance of the symbol-based scheme is better than that of the slot-based scheme (compare red and black results with the circle symbol).



Figure 1 – Performance of symbol-based and slot-based OCC schemes for 3.75kHz SCS (from R1-2405842 – Huawei)

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 2), 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 2 Symbol-level OCC with $N\_{RU}=1, N\_{slots}^{UL}=16, N\_{rep}=8, N\_{slot}=1$ and *L*=2 (from R1-2405842 – Huawei)

This spreading operation is probably also required for a cross-slot scheme, as illustrated in Figure 3.



Figure 3 Slot-level OCC with $N\_{RU}=1, N\_{slots}^{UL}=16, N\_{rep}=8, N\_{slot}=1$ and *L*=2 (from R1-2405842 – Huawei)

It is hence proposed that a cross-symbol OCC scheme is supported for 3.75kHz SCS single-tone:

**[FL1] Proposal 4.2-1: For 3.75kHz single-tone transmission, cross-symbol OCC is supported.**

Companies are invited to comment on proposal 4.2-1. Companies could comment on:

* Whether you support the proposal
* Is there better wording?
* Is it clear that cross-slot is not also supported (it is assumed that a single scheme would be supported)

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Qualcomm | OK |
| Lenovo | I am confused how to get the proposal based on the summary of supporting companies below.**3.75kHz OCC scheme*** symbol: QC, Samsung, LGE, Spreadtrum
* Slot: Apple, MTK, Sharp, CATT, OPPO, Interdigital, CMCC, HW
 |
| Ericsson | Ok upon adding the following clarifications to keep the wording aligned with respect to previous agreements:**Proposal 4.2-1: For 3.75kHz SCS single-tone transmission** **OCC for NPUSCH format 1, ~~cross-symbol OCC~~** **symbol-level OCC is supported.** |
| LGE | We support the proposal. Considering the target frequency offset, cross-symbol OCC would be better than the cross-slot OCC for 3.75kHz SCS.  |
| TCL | OK |

**[FL1] Proposal 4.2-2: For 3.75kHz single-tone transmission with cross-symbol OCC, symbols are spread (repeated) by the OCC factor before OCC is applied. The RU length is increased by the spreading factor.**

Companies are invited to comment on proposal 4.2-1. Companies could comment on:

* Whether you support the proposal.
* Is there better wording?
* Is there a different way in which the physical channel mapping would be changed for cross-symbol OCC?

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Qualcomm | OK |
| Lenovo | Whether to redefine the “RU” needs further study. I think there is no need to have such new definition. |
| Ericsson | Ok upon adding the following clarifications to keep the wording aligned with respect to previous agreements:**Proposal 4.2-2: For 3.75kHz SCS single-tone transmission OCC for NPUSCH format 1 with ~~cross-symbol OCC~~ symbol-level OCC, symbols are spread (repeated) by the OCC factor before OCC is applied. The RU length is increased by the spreading factor.** |
| LGE | We are fine with the first part, but we need to carefully check the impact on the RU length increase. RU length may consist of two parts: one is the number of symbols, and the other is the number of slots. It would be better to clarify which part will be increased. At this moment, considering the coexistence with the legacy UE, we prefer to keep the existing RU length. Instead, to compensate the TBS, we can consider redefining the mapping between N\_RU and I\_RU for TBS determination.  |
| TCL | We agree with the first part of the proposal. However, we perfer to the keep the legacy RU length. |
|  |  |

## 15kHz single-tone OCC scheme

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

**15kHz OCC scheme**

* symbol: [Ericsson][Samsung]
	+ 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]
	+ Better performance and standards impact of cross-slot and cross-symbol are similar [Samsung]
	+ Physical channel mapping spec impact [OPPO][vivo][ZTE][CMCC] [Spreadtrum] [HW]
		- Consider impact on code rate [vivo]
		- Spread first [HW]
	+ Better performance [ZTE]
		- Higher tolerance to timing and frequency offset [ZTE]
* slot: [MTK][Sharp][LGE][CATT][OPPO][Interdigital][CMCC][Spreadtrum][HW]
	+ Minimal spec impact [OPPO]
	+ Simulation results show similar performance to symbol level [OPPO][CMCC][HW]
		- Note: 15kHz SCS has shorter time span than 3.75kHz SCS [CMCC]
	+ Physical channel mapping spec impact[vivo][ZTE][CMCC] [Spreadtrum][HW]
		- Consider impact on code rate [vivo]
		- Spread first [HW]
	+ Better performance [ZTE]
		- Higher tolerance to timing and frequency offset [ZTE]
	+ Allows common design with multi-tone [Spreadtrum]
* Nslot [ZTE]
	+ Minimum changes to physical channel mapping [ZTE]
	+ Performance impacted by frequency and timing offset [ZTE]
* Supported OCC lengths:
	+ 2: Apple, MTK, CATT, HW
	+ 4: Apple, MTK
		- OCC4 is about 2.5dB worse than OCC2 [CATT]
		- No throughput gain from OCC4 [HW]

At 15kHz SCS, there is less difference in the performance of cross-symbol and cross-slot OCC, as observed by several companies, including vivo and Huawei. The performance difference is lower because the timespan of the OCC codewords is lower and the OCC operation is less affected by CFO over that shorter timespan. Performance comparison between these schemes are shown in Figure 4 (the SNR offset from the baseline scheme is assumed to be due to a code rate issue) and Figure 5.



Figure 4 – Performance comparison between cross-symbol and cross-slot OCC (from R1-2406205 – vivo)

|  |  |
| --- | --- |
| 1. OCC2
 | (b) OCC4 |
|  |  |

Figure 5 - Performance of 15 kHz Single-tone NPUSCH format 1 w/ and w/o OCC (from R1-2405842 – Huawei)

While it would be possible to adopt different OCC schemes for 15kHz SCS and 3.75kHz SCS, this would seem to create complexity in the specification. However, if a cross-slot scheme were adopted for 15kHz, it would seem that there would not be a significant performance loss from adopting the cross-slot scheme.

As a first step, it might be good to try to agree that a common scheme is adopted for 3.75kHz and 15kHz SCS.

**[FL1] Proposal 4.3-1: 15kHz SCS uses the same OCC scheme as for 3.75kHz SCS.**

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

* Whether you support the proposal.
* Is there better wording?
* What would be the point in adopting different OCC schemes for the two SCS, considering performance and specification impact for example?

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Lenovo | If slot-based OCC solution is adopted for 3.75KHz, we support the proposal. |
| Ericsson | Ok to aim for a common design. The following clarifications are aimed to keep the wording aligned with respect to previous agreements:**[FL1] Proposal 4.3-1: 15kHz SCS single-tone transmission OCC for NPUSCH format 1 uses the same OCC scheme as for 3.75kHz SCS single-tone transmission OCC for NPUSCH format 1.** |
| LGE | In our understanding, the mapping is already different between 15kHz SCS and 3.75kHz SCS. In this point of view, we do not need to think that they should use the same OCC scheme. We can use different OCC scheme depending on the SCS.  |
| TCL | We are fine with the proposal. |
|  |  |

## Multi-tone OCC scheme

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

**Multi-tone OCC scheme**

* symbol:
* slot / Nslot [CATT] [Interdigital][CMCC][HW]
	+ Minimum specification impact [CATT][CMCC][HW]
	+ Unified design with single-tone [CATT]
	+ Evaluation of OCC2 or OOC4 show large throughput gain and minimal SNR loss [ZTE]
	+ Slot level has better performance than RV-level [CMCC]
	+ Nslot performance degrades relative to slot performance due to longer time extent [HW]
* Repetition / RV-level
* Pre-DFT
	+ Different designs would be needed for different numbers of tones [CATT][vivo]
	+ Specification work would not be applicable to single-tone and hence generates more workload [OPPO]
* Time-domain approach common to single-tone [Xiaomi][OPPO][vivo]
* Whether to support multi-tone:
	+ No: Ericsson, Samsung,Interdigital
		- 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]
		- Why wouldn’t you just do FDM of single-tone and achieve the same multiplexing gain? [Samsung][ZTE][Interdigital]
	+ Yes: Viasat, Lenovo, CMCC
		- Newer satellites and HPUE make this viable [Viasat]
		- Fast beam hopping favours multi-tone. Good to transmit data before the beam hops [Viasat]
		- Minimal physical channel mapping impact [ZTE]
	+ Common time-domain solution with single-tone [Nok][Spreadtrum]
		- Different schemes would increase eNB complexity
		- Single-tone scheme is baseline, see whether it can be applied to multi-tone [Spreadtrum]

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.

It seems like a first step would be to decide whether multi-tone OCC will be supported. If it is supported, we could then try to choose between a slot-based or an Nslot-based approach, or simply decide that a time-domain approach will be applied.

**[FL1] Question 4.4-1: Should RAN1 support multi-tone OCC in Rel-19?**

Companies are invited to comment on question 4.4-1. Companies could comment on:

* Do you have wording for a proposal?
* If multi-tone is supported, how can RAN1 minimise work and achieve commonality in the specs? Maybe multi-tone could strive to use the same OCC scheme as 15kHz SCS single-tone.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Qualcomm | We do not see a strong view to support multi-tone OCC (we actually don’t see a strong reason to even support 15kHz single tone) |
| Lenovo | The WID target is the uplink capacity enhancement, why not support multi-tone OCC? |
| Ericsson | No. Applying the same OCC scheme used for single-tone to the multi-tone casedoes not seem to be possible, mainly because for single-tone the allocationin the frequency-domain is constant (1-tone), whereas for multi-tone theallocation in the frequency-domain is variable (i.e., either 3, 6, or 12 tones).The OCC mapping is foreseen to be impacted. |
| LGE | From our side, if the repetition is allowed for multi-tone NPUSCH, and if the mapping does not need to be changed highly, we can consider the multi-tone OCC as well.  |
| TCL | In our opinion, the mapping between signle-tone and multi-tone is different. If we support the multi-tone OCC, we should take the common design into consideration. |
|  |  |

## Maximum number of UEs that can be OCC-ed: M = 2 or M = 4?

The following issues were raised related to the supported OCC lengths for NPUSCH format 1:

* 3.75kHz: Supported OCC lengths:
	+ 2: QC, Apple, Ericsson, MTK, Sharp, HW
	+ 4: QC, Apple, MTK, Sharp
		- SNR degradation up to 0.5dB [QC]
		- No throughput gain from OCC4 [HW]
		- 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]
* 15kHz Supported OCC lengths:
	+ 2: Apple, MTK, CATT, HW
	+ 4: Apple, MTK
		- OCC4 is about 2.5dB worse than OCC2 [CATT]
		- No throughput gain from OCC4 [HW]

Assuming that OCC transmission is beneficial, it would seem that at least OCC2 would be supported, since 2 is the minimum integer greater than 1. The question is whether RAN1 also supports OCC4.

There are several issues with the support of OCC4:

* Some simulations show poor performance of OCC4 in comparison to OCC2. For example, the results below (Figure 6) from Huawei clearly shown that OCC4 is less robust than OCC2. Xiaomi and Qualcomm also show a performance loss for OCC4. Note that ZTE do not show a significant performance degradation for multi-tone with a cross-Nslot scheme.
* Huawei report that the aggregated throughout of OCC4 is similar to that for OCC2
* Downlink signalling will be more of a bottleneck for OCC4 than it already is for OCC2
* Specification changes to DL signalling (k0 values between NPDCCH and NPUSCH) may be required with OCC4
* Pairing is problematic for OCC. It becomes increasingly difficult to find UEs with similar power, location, gap locations, number of repetitions etc. with OCC4 compared to OCC2

|  |  |
| --- | --- |
| 1. OCC2
 | (b) OCC4 |
|  |  |

Figure 6 - Performance of 15 kHz Single-tone NPUSCH format 1 w/ and w/o OCC (from R1-2405842 – Huawei)

Based on the issues identified above, it is proposed that M = 2 is the maximum OCC factor in Rel-19.

**[FL1] Proposal 4.5-1: For OCC of NPUSCH format 1, RAN1 supports multiplexing of up to 2 UEs via OCC.**

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

* Whether you support the proposal.
* Is there better wording?
* If you support OCC4, why OCC4 is practical, given the issues identified in the text above?

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Qualcomm | We think it is premature to rule out OCC4. Based on our evaluations, the degradation of OCC4 is very small.Regarding the DL overhead issues, we could restrict the cases in which OCC4 can be used (for example, RACH-less EDT is a clear use case in our view). |
| Leonvo | OCC 4 should be supported |
| Ericsson | Supporting “up to 2 UEs via OCC” is preferred. There reason is that finding suitable candidate UEs that match similar characteristics will become more difficult as more UEs are sought to be matched. Moreover, there is a lack of scheduling delays “k0” for the 4 DCIs to point out the exact same UL resources (even for the 2 UEs case an additional scheduling delay “k0” is foreseen to be required). |
| TCL | OCC 4 should also be supported. |
|  |  |

## DMRS

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

**DMRS multiplexing type**

* CDM: QC, ETRI, ZTE
	+ Improved channel estimation at 15kHz [CATT]
	+ Minimal SNR loss in simulated results for OCC2 [QC][OPPO][ZTE]
		- Minimal SNR loss at 15kHz [HW]
		- Large SNR loss at 3.75kHz [HW]
	+ Create by spreading DMRS sequence and then applying OCC [QC]
	+ Create by masking legacy DMRS sequence with OCC sequence [vivo]
* TDM: Lenovo
	+ 0.2dB loss compared to CDM for OCC2 (CFO assumed): QC
	+ >1dB loss compared to CDM for OCC4 (CFO assumed): QC
	+ 2dB performance loss with OCC2 for Nslots: ZTE
	+ 15kHz
		- OCC2: 0.8dB performance loss [HW]
		- OCC4: 2.5dB performance loss [HW]
	+ 3.75kHz
		- OCC2: TDM is 4.5dB better than CDM due to multi-user interference with CDM with CFO
	+ Performance loss of TDM 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]
	+ RAN1 discuss detailed candidates for TDM mapping [OPPO]
	+ Create by masking legacy DMRS sequence with 1/0 pattern [vivo]
	+ 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
* Depends on SCS [CATT]
	+ 15kHz:
		- CDM [CATT
			* Simulated performance is 6dB better than TDM [CATT]
		- TDM
	+ 3.75kHz
		- CDM
			* Loss of orthogonality means CDM doesn’t work [CATT]
				+ Note: probably depends on the DMRS pattern assumed [FL]
		- TDM [CATT]
* Multi-tone
	+ Cyclic shifts [CATT][HW]
		- Existing cyclic shift mechanism can be used [CATT][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 6 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. 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 7 – Structure of TDM and CDM multiplexing schemes (from R1-2406133 – 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).

Hence, it is proposed that for 15kHz SCS, a CDM DMRS scheme is adopted. Since there are concerns about CDM performance at 3.75kHz SCS [HW] and the viability of the alternative of TDM DMRS [LGE], it is proposed that the DMRS scheme for 3.75kHz is FFS.

**[FL1] Proposal 4.6-1:**

* **For 15kHz SCS:**
	+ **At least for single-tone transmissions, DMRS for OCC UEs use CDM**
* **For 3.75kHz SCS:**
	+ **RAN1 chooses between:**
		- **Option 1: DMRS for OCC UEs use CDM**
		- **Option 2: DMRS for OCC UEs use TDM**

Companies are invited to comment on question 4.6-1. Companies could comment on:

* Do you have better wording for the proposal?
* Can we choose between CDM and TDM already?
* Beyond performance and the “phase continuity due to blanking for TDM” issues, are there any other issues that should be considered?

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Qualcomm | We would be OK with this proposal, but one issue we see is that there are two (or more) “CDM” flavors: one that keeps the same DMRS location as Rel-17, and one that has new locations. |
| Lenovo | It depends on the OCC scheme; we are open to support DMRS OCC use CDM or TDM. |
| Ericsson | In our understanding, for NPUSCH Format 1 with 15 kHz SCS given the slot duration is 0.5 ms, the DMRS symbol is just spread as any other symbol in the slot, is that what is meant by CDM?On the other hand, for NPUSCH Format 1 with 3.75 kHz SCS given the slot duration is 2 ms, the DMRS symbol requires some modification (e.g., in its location) while keeping “DMRS overhead” the same as for Rel-17, then it will be spread as any other symbol in the slot, that is what we had understood as CDM? Because of the above, we think that the proposal should only be related to NPUSCH Format 1 with 3.75 kHz SCS, that is: **[FL1] Proposal 4.6-1:*** **~~For 15kHz SCS:~~**
	+ **~~At least for single-tone transmissions, DMRS for OCC UEs use CDM~~**
* **For NPUSCH Format 1 with 3.75kHz SCS:**
	+ **RAN1 chooses between:**
		- **Option 1: DMRS for OCC UEs use CDM**
		- **Option 2: DMRS for OCC UEs use TDM**
 |
| LGE | Regarding the TDM, it will cause non-contiguous transmission in time domain. In general, during the non-contiguous transmission, the phase-continuity among different contiguous sets will not be guaranteed in general. In this case, fi some contiguous set does not have its own DMRS symbol, it would not be possible to perform channel estimation. If the TDM approach allows the case where contiguous set of the non-contiguous transmission does not include DMRS, it is not preferrable. Moreover, for 3.75kHz SCS, it is observed that the different companies have different result on whether TDM or CDM is better.  |
|  |  |

The DMRS sequence for NPUSCH is defined in TS36.211 section 10.1.4.1.1:

|  |
| --- |
| The reference signal sequence for  is defined by where the binary sequence  is defined by clause 7.2 and shall be initialised with  at the start of the NPUSCH transmission. The quantity  is given by Table 10.1.4.1.1-1 where  for NPUSCH format 2, and for NPUSCH format 1if group hopping is not enabled, and by clause 10.1.4.1.3 if group hopping is enabled for NPUSCH format 1. |

It is suggested by vivo, TCL and Nokia that the DMRS sequence needs updating for OCC. For example, Nokia propose that the w(n) sequence is a function of both cell ID and OCC index. This would seem to be an alternative to the CDM and TDM schemes.

**[FL1] Question 4.6-2:**

**Should RAN1 consider changes to the DMRS sequences applied for OCC?**

Companies are invited to comment on question 4.6-2. Companies could comment on:

* Is the use of different DMRS sequences an alternative to TDM / CDM?
* Even if we used TDM or CDM, would we need to apply different DMRS sequences for OCC?
* Is the change to the DMRS sequence limited to the choice of row in Table 10.4.1.1-1 of TS36.211?

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Qualcomm | If we want the DMRS to be orthogonal, we need to keep the same scrambling across all UEs + apply an orthogonal code on top. There are different ways to achieve this, which we are open to discuss. |
| Ericsson | Before treating this proposal, it is important to decide on Proposal 4.2-1 and Proposal 4.3-1 (i.e., symbol-level or slot-level OCC spreading for 3.75 kHz SCS and 15 kHz SCS). |
| LGE | For cell randomization, we may need to consider this. However, rather than changing the value of u, we may need to change the value of c\_init.  |
|  |  |
|  |  |

The following views were expressed about DMRS pattern:

**3.75kHz DMRS pattern**



* Within cluster separation is x1 symbols, between cluster separation is x2 symbols [QC][Ericsson][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][Ericsson]
	+ X1 = 0 [LGE]
	+ Slot-level OCC cannot be used as the slots have different structures [HW]
* Study performance comparison of different patterns [ETRI]
* New DMRS pattern is required [QC][Ericsson][NEC][LGE]
* 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][Spreadtrum]
	+ Orthogonal DMRS are applied to UEs and eNB can distinguish [Spreadtrum]

**15kHz DMRS pattern**

* Legacy DMRS pattern used [Ericsson][NEC][LGE]
	+ No issues with pull-in range, so no need for a change [Ericsson]
* Study performance comparison of different patterns [ETRI]
* 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]

There seems to be general agreement that a new DMRS pattern would be required for 3.75kHz SCS and that a legacy DMRS pattern is OK for 15kHz SCS. This new pattern would be required by either a TDM or a CDM DMRS scheme. The following proposal is hence made:

**[FL1] Proposal 4.6-3**

* **Two consecutive DMRS symbols (before spreading) are separated by either** $x\_{1}$ **(“short separation”) or** $x\_{2}$ **(“long separation”)**

**FFS: Detailed structure and values of** $x\_{1}$ **and** $x\_{2}$**.**

Companies are invited to comment on proposal 4.6-3. Companies could comment on:

* Do you have better wording for the proposal?
* Is another structure preferred?
* Do you agree that this new structure would be required if either TDM or CDM DMRS were applied?

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| **Company** | **Comment** |
| Qualcomm | OK |
| Ericsson | In our understanding **Proposal 4.6-3** should be related only to NPUSCH Format 1 with 3.75 kHz SCS. We think that before treating this proposal we should decide whether CDM or TDM is going to be supported for NPUSCH Format 1 with 3.75 kHz SCS. |
| LGE | We also need to add one more parameter which is the symbol offset x\_3 to indicate the first DMRS symbol position.  |
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## 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]
	+ Consider that there are different UL segment gap dropping rules (symbol, slot) [Spreadtrum]
* TDM DMRS introduce transmission gap when the DMRS is muted [LGE]
* Guard periods for 3.75kHz UL transmissions [offline discussion at RAN1#118]

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:

* UL gaps for synchronization (from Rel-13)
* Gaps around NPRACH occasions
* UL timing adjustment gaps for NTN (from Rel-17)
* TDM DMRS that are muted
* Guard periods for 3.75kHz UL transmissions

RAN1 could study potential solutions for operating OCC when there are UL gaps. RAN1 can further identify potential methods to tolerate the UL gaps (such as dropping OCC codewords that partially overlap, postponing OCC codewords etc.). Alternatively, the UL gap issue could motivate another choice in this work item (e.g. between OCC scheme or OCC2 vs OCC4 support).

**[FL1] Proposal 4.7-1:**

**RAN1 studies whether the following types of UL transmission gap will impact the design of OCC for IoT-NTN**

* **UL gaps for synchronization (from Rel-13)**
* **Gaps around NPRACH occasions**
* **UL timing adjustment gaps for NTN (from Rel-17)**
* **TDM DMRS that are muted**
* **Guard periods for 3.75kHz UL transmissions**

Companies are invited to comment on proposal 4.7-1. Companies could comment on:

* Do you have better wording for the proposal?
* Is this a complete list of UL gaps?
* What problems are UK gaps likely to cause (loss of orthogonality on either side of the gap?)
* What are the potential solutions (dropping, postponing etc), if the UL gaps cause problems.
* Does the UL gap issue motivate a certain OCC scheme?

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| **Company** | **Comment** |
| LGE | We can consider shortened OCC codeoword if the UL gap is few symbols for cross-symbol OCC. We can consider drop some portion of UL transmission overlapping with UL gap for cross-slot OCC if the UL gap is few symbols.Or, for simplicity, it can be considered that when OCC can be applied to the NPUSCH, the UE does not expect that the UL gap is not a unit of a slot especially for the UL timing adjustment gaps for NTN.  |
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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]
	+ Need clarification, assuming OCC is not applied to Msg3 [Xiaomi]
* PUR [QC][TCL]
* 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.

## 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]
* Signalling method:
	+ 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).

 **[FL1] Question 4.9-1:**

**Which of the following items need to be signalled for OCC operation:**

* **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.,).**

Companies are invited to comment on question 4.9-1. Companies could comment on:

* Items that could be added to the list
* Items that could be removed from the list
* Any views on the amount of signalling (number of bits) or the signalling type (DCI, RRC, implicit etc).

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| **Company** | **Comment** |
| LGE | At least OCC codeword and OCC feature enabling need to be provided to the UE. Depending on the design, OCC scheme, OCC factor may not be needed to be provided explicitly.  |
| TCL | All the four items need to be provided to UE. OCC factor, OCC feature enabling and OCC scheme can be provided by RRC or DCI depend on whether it is semi-statical or dynamic. OCC codeword needs to be indicated to UE by DCI explicitly or implicitly because there are several codewords can be choosed. |
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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.

**[FL1] Question 4.10-1:**

**Is it likely that issues of device pairing will affect the OCC specification?**

Companies are invited to comment on question 4.10-1. Companies could comment on:

* Which aspects of specification could be impacted.
* Whether the pairing issues suggest that a certain type of OCC scheme or OCC parameterisation (e.g. only support OCC2) are preferred
* Whether device pairing issues require additional consideration in the evaluation assumptions (the assumptions already consider power imbalances for example).

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| **Company** | **Comment** |
| LGE | How to perform pairing for multiplexing via OCC would be up to network implementation. The important thing is that the assumption on the UE pairing will affect to the OCC scheme design. For instance, when we assume that the proper device paring can be used, then we can consider cross-slot OCC even for 3.75kHz SCS.  |
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## Downlink Issues

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]

The increase in required NPDCCH resource seems to be an issue that might be used to choose a maximum OCC factor (e.g. to choose between OCC2 and OCC4). Increasing the amount of NPDCCH resource would seem to be out of scope of this work item.

The alignment of NPUSCH resources through k0 signalling may require further study.

**[FL1] Question 4.11-1:**

**Should RAN1 consider supporting new k0 values (time between NPDCCH and NPUSCH) in order to support OCC?**

Companies are invited to comment on question 4.11-1. Companies could comment on:

* Should RAN1 further study this issue?
* What k0 values would be required?

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| **Company** | **Comment** |
| Ericsson | Yes, especially if the intention were to support up to 4 OCC UEs (please note that even in the case of supporting 2 OCC UEs, an additional scheduling delay “k0” is foreseen to be required). |
| LGE | We do not need to introduce new k0 values. In case of cross-symbol OCC, it is straightforward, even though two different UL transmissions have different starting positions, multiplexing via different OCC codeword would not be a problem. In case of cross-slot OCC, depending on the NPDCCH locations, it is possible to align the time duration applying OCC codewords across different UL transmissions.  |
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# NPRACH

## Overall summary of issues raised in Tdocs

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

**Support or not**:

* Support [QC][Lenovo][NEC]
* Not support [Ericsson][CATT][vivo][Spreadtrum]
	+ Reasons:
		- Backward compatibility [Ericsson]
		- Specification impact [Ericsson][CATT][vivo][Spreadtum][HW]
			* New NPRACH format required accounting to CP issue [CATT]
		- NPRACH is not the bottleneck [CATT][vivo][Spreadtrum][HW]
		- Performance with power imbalance, timing error [HW]

**OCC scheme**

* Cross-symbol [QC][ETRI][NEC][Lenovo][ZTE]
	+ 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 [Sharp][CATT][Xiaomi][TCL][Spreadtrum]
	+ 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][TCL]
	+ Time span is too long and leads to loss of orthogonality [QC][CATT][Spreadtrum][HW]
	+ 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]
* 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]

**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]

In this version of the FLS, there are sufficient issues to consider for NPUSCH. It is proposed to come back to these NPRACH issues in a future update of this document.

# Tuesday 20 August: offline proposals for discussion

**TBD**

# Conclusions

This document is the feature lead summary for IoT-NTN in RAN1#118. 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] R1-2405493 “FL Summary #1 for IoT-NTN”. RAN1#117, Fukuoka, Japan. Moderator (Sony)

[3] R1-2405494 “FL Summary #2 for IoT-NTN”. RAN1#117, Fukuoka, Japan. Moderator (Sony)

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

R1-2405842 Discussion on UL capacity enhancements for IoT NTN Huawei, HiSilicon

R1-2405928 Discussion on IoT-NTN uplink capacity/throughput enhancement Spreadtrum Communications

R1-2406006 Discussion on the IoT -NTN uplink capacity/throughput enhancements CMCC

R1-2406077 Discussion on the IoT-NTN uplink capacity/throughput enhancements TCL

R1-2406111 IoT-NTN uplink capacity/throughput enhancement InterDigital, Inc.

R1-2406133 Discussion on UL capacity enhancement for IoT NTN ZTE Corporation, Sanechips

R1-2406205 Discussion on IoT-NTN uplink capacity enhancement vivo

R1-2406232 Discussion on IoT-NTN uplink capacity/throughput enhancement OPPO

R1-2406278 Discussion on IoT-NTN uplink capacity enhancement Xiaomi

R1-2406362 Discussion on UL capacity enhancement for IoT NTN CATT

R1-2406427 IoT-NTN uplink capacity enhancement Nokia, Nokia Shanghai Bell

R1-2406449 Discussion on IoT-NTN uplink capacity/throughput enhancement LG Electronics

R1-2406512 Discussion on uplink capacity enhancement for IoT NTN Lenovo

R1-2406556 IoT-NTN uplink capacity/throughput enhancement NEC

R1-2406573 IoT NTN OCC methods for NPUSCH and NPRACH Sharp

R1-2406673 Discussion on uplink capacity/throughput enhancement for IoT-NTN Samsung

R1-2406741 Discussion on uplink capacity/throughput enhancement for IoT NTN ETRI

R1-2406780 IoT-NTN - uplink capacity/throughput enhancemen MediaTek Inc.

R1-2406809 On uplink capacity enhancements for IoT-NTN Ericsson

R1-2406866 On IoT-NTN Uplink Capacity Enhancement Apple

R1-2407052 IOT-NTN uplink capacity/throughput enhancement Qualcomm Incorporated

R1-2407138 Views on UL Capacity Enh for IoT-NTN Inmarsat, Viasat