**3GPP TSG RAN WG1 #110 R1-220xxxx**

**Toulouse, France, August 22nd – 26th, 2022**

**Source: Moderator (Intel Corporation)**

**Title: Summary#1 of AI: 9.9.1 NR PDCCH reception in symbols with LTE CRS REs**

**Agenda item: 9.9.1**

**Document for: Discussion and Decision**

# Introduction

In RAN#94-e meeting a work item on eDSS support was agreed for Rel-18 [1]. The objectives of the WID include enhancements to NR PDCCH reception as shown below:

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| The following objectives shall be included for improvement of NR spectrum efficiency for LTE-NR co-existence (RAN1):  • Study and if needed specify NR PDCCH reception in symbols with LTE CRS REs. [RAN1] |

This document contains summary of the companies’ and moderator’s proposals.

# Review and observations

The following are observations from the FL based on tdoc review. This section is not meant for agreement.

**PDCCH capacity:**

Multiple companies submitted results although different assumptions on Tx (puncturing/superposition), receivers, UE distributions, capacity calculation methodology etc. is expected to cause variation of results across companies. The numbers in the following table represent PDCCH capacity gain % with respect to baseline (no enhancement). The variation of gain numbers from within a company depends on factors such as receiver channel estimation algorithm used, UE speed, fraction of legacy vs Rel-18 UEs in the system, CORESET configuration etc.

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| --- | --- | --- | --- |
| Scenarios | Option 1-1 | Option 1-2 | Option 2 |
| Scenario 1A |  |  | 24, 61 (Huawei)  68 (ZTE)  69, 33 (Vivo)  49, 51, 71, 73 (Mediatek)  38, 65, 70, 76 (Qualcomm)  47,67,77 (Ericsson)  25, 60 (Spreadtrum) |
| Scenario 1A-2 |  |  | 13,32 (Huawei) |
| Scenario 2 | 44 (Huawei)  27, 54 (ZTE)  -32,7, 33, 56, 59 (Vivo)  -16, 3, 16, 28, 29 (Vivo)  38, 40, 44, 48 (Mediatek)  70, 82 (Qualcomm)  19,33 (Ericsson)  -6, 28, 36 (Spreadtrum) | 66, 33 (Vivo)  49, 51 (Mediatek)  140 (Qualcomm)  25 (Ericsson)  46 (Spreadtrum) | 2, 48 (Huawei)  29,59 (ZTE)  30,31,53,53 (Mediatek)  54,77,91,97 (Qualcomm)  19, 38 (Ericsson) |
| Scenario 3 | 14 (Huawei)  -47, 7, 17, 21, 29 (Vivo)  -23, -3, 8, 10, 14 (Vivo)  20, 20, 23, 24 (Mediatek)  32, 34 (Qualcomm)  14, 19 (Ericsson) | 28,14 (Vivo)  24,28 (Mediatek)  36 (Qualcomm)  17 (Ericsson) | -9, 12 (Huawei)  12, 14, 26, 27 (Mediatek)  12, 30, 33, 34 (Qualcomm)  11, 21 (Ericsson) |
| LTE BW<NR BW (Huawei) | 4 (Huawei) |  |  |
| modified Scenario 3 (2+1 symbol Rel-18 CORESET) (Ericsson) | 14,24 (Ericsson) | 19 (Ericsson) | 15,24,29,34,39 (Ericsson) |

One or more companies have raised the following observations or comments:

**Outage performance**

* worse outage performance than baseline observed for options 1-1, and 2 (gNB puncturing or superposition)

**LTE impact**:

* degradation of LTE throughput due to Option 2 superposition
* decrease for LTE PDCCH capacity for scenario 1A, 2

**Coexistence with legacy NR UEs**:

* capacity gain of option 1-1 in Scenario 2 would reduce significantly from the case of 100% NR Rel-18 UE distribution to 50% NR Rel-18 UE distribution
* TDM/FDM of CORESET with legacy
* 2 symbol CORESET requirement for 1-1 and 1-2 is problematic due to CORESET#0

**Complexity**:

* new rate-matching for Option 1-2
* Option 1-2 is out of WI scope
* Channel estimation complexity beyond clean symbol DMRS estimation, multiple UE implementation options
* significant impact to channel estimation for option 1-1 and option 2
* fragmentation of UE capabilities
* 1-symbol CORESET with puncturing/superposition demands advanced receiver/channel estimator

**Specification work:**

* RAN1 - remove the restriction in TS 38.213, additional PDCCH mapping rule, applicable search space set, how to indicate the LTE CRS pattern(s) for PDCCH
* RAN4 - performance requirements and test-cases potentially for different receiver options

**Not critical enhancement - already available tools**

* FG 3-2, FG 3-5, or FG 22-12
* Rel-17 SCell PDCCH scheduling PCell PDSCH/PUSCH

**Other detailed proposals**

* Assistance information to UE (indication to puncture for example in Option -2)
* Restriction (specified or configured) on applicability to search spaces, RRC connected UEs, 2-3 symbol CORESETs
* Indication of CRS patterns for PDCCH

# Proposals

## Principle

The intention here is to check if we can select one of following options in principle that we can then use to work on TPs or detailed proposals-

**Proposal:**

Select one of the following PDCCH enhancements (in principle):

**Option 1-1**: No NR-PDCCH-DMRS is transmitted for only the REs overlapping with LTE-CRS of the OFDM symbol, NR-PDCCH is punctured on REs colliding with LTE-CRS, NR-PDCCH must span at least 2 consecutive symbols with at least 1 symbol not overlapping with LTE-CRS

* PDCCH and PDCCH DMRS mapping to REs: Legacy
* PDCCH REs overlapping with LTE CRS: Receiver punctures
* PDCCH DMRS REs overlapping with LTE CRS: All DMRS REs on overlapping symbol Not used for CE, or legacy pattern is assumed
* gNB transmits: Irrelevant what the gNB transmits on REs overlapping with the LTE CRS REs as indicated in the CRS RM pattern.
* Channel estimator: operate on clean symbol DMRS only, Legacy

**Option 1-2**: No NR-PDCCH-DMRS is transmitted in any RE of the OFDM symbol, NR-PDCCH is transmitted on REs not colliding with LTE-CRS including the original DMRS, NR-PDCCH is punctured on REs colliding with LTE-CRS, NR-PDCCH must span at least 2 consecutive symbols with at least 1 symbol not overlapping with LTE-CRS

* PDCCH and PDCCH DMRS mapping to REs: New PDCCH rate-matching
  + No PDCCH DMRS on the symbol overlapping with LTE CRS
* PDCCH REs overlapping with LTE CRS: Receiver punctures
* PDCCH DMRS REs overlapping with LTE CRS: Not expected
* Channel estimator (UE assumption): Operate on clean symbol DMRS only
* gNB transmits: Irrelevant what the gNB transmits on REs overlapping with the LTE CRS REs as indicated in the CRS RM pattern

**Option 2:** NR-PDCCH or NR-PDCCH-DMRS is transmitted on REs not colliding with LTE-CRS, NR-PDCCH and NR-PDCCH-DMRS may or may not be punctured on REs colliding with LTE-CRS

* PDCCH and PDCCH DMRS mapping to REs: Legacy
* PDCCH REs overlapping with LTE CRS: Baseline: Process as legacy
* PDCCH DMRS REs overlapping with LTE CRS: Aware or unaware
* Channel estimator: Baseline: Process as legacy (Receiver does not puncture DMRS), Optional: Advanced receiver (Use the DMRS other than legacy behavior)
* gNB transmits:
  + Baseline: May puncture the PDCCH/PDCCH DMRS, or may superposition the two.
  + Optional: may puncture LTE CRS of Port#2&3.
  + Impact to LTE UEs should be considered if superposition is used.

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| --- | --- |
| Company | Comment |
| Huawei/Hisi | As summarized by moderator, a number of concerns are received over all the 3 options. From our observations:   * Option 2 with punctured transmission has no appealing capacity gain (-9.3%/2.8%/24.1% for scenario#1A/2/3, respectively), and has deteriorated outage (as high as 26.8% under scenario#1A). Note that though for some scenarios, there are capacity gain, but as Option 2 cannot serve the cell edge UEs, its capacity gain attributes to a large extent to the scheduling gain of cell centre UEs with small AL values. So the capacity gains are somewhat overestimated. * Option 2 with superposition with LTE CRS (i.e., Option 2B) will cause degraded performance of LTE, which is unfriendly to the incumbent system. * In addition, as mentioned by some other companies and observed from simulation results over companies, the performance of Option 2 quite depends on the UE receiver which differ a lot over UEs, so that will cause nontrivial work load to RAN4. * Option 1-2 will introduce challenging UE implementation complexity on supporting new PDCCH RM/CE/demodulation patterns. Our understanding that, the scope of the Objective 1 for this SI is built on the assumption that UE has no capability of new PDCCH RM patterns; otherwise why not allow UE to perform PDCCH RM around the LTE CRS (which is out of scope) rather than being punctured? * Option 1-1 seems the simple solution with promising gains, but this gain is achieved still under quite limited case of Scenario 2 with LTE bandwidth = NR bandwidth and without co-existence with legacy NR UEs. That means, even Option 1-1 is scenario restricted and cannot provide universal gain.   Based on the analysis above, at the moment we do not observe a strong necessity to introduce any of the options in R18. |
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# References

[1] RP-213575, New WI: Enhancement of NR Dynamic spectrum sharing (DSS), Ericsson, 3GPP TSG RAN Meeting #94e, Electronic Meeting, Dec. 6 - 17, 2021.

[2] R1-2205864, Discussion on NR PDCCH reception in symbols with LTE CRS REs Huawei, HiSilicon

[3] R1-2205964 Discussion on NR PDCCH reception for DSS ZTE

[4] R1-2206003 Discussion on NR PDCCH reception in symbols with LTE CRS REs Spreadtrum Communications

[5] R1-2206057 Discussion on PDCCH reception on CRS symbol vivo

[6] R1-2206324 Discussion on NR PDCCH reception in symbols with LTE CRS REs Oppo.

[7] R1-2206432 DSS – NR PDCCH overlapping with LTE CRS Nokia, Nokia Shanghai Bell

[8] R1-2206842 On PDCCH receptions in symbols with LTE CRS Samsung

[9] R1-2207011 Discussion on NR PDCCH reception in symbols with LTE CRS REs Mediatek

[10] R1-2207039 Discussion on NR PDCCH reception in symbols with LTE CRS REs LG

[11] R1-2207130 Evaluation of NR PDCCH overlapping with LTE CRS InterDigital

[12] R1-2207249 NR PDCCH reception in symbols with LTE CRS REs Qualcomm

[13] R1-2207347 Discussion on NR PDCCH reception in symbols with LTE CRS REs Apple

[14] R1-2207422 Discussion on NR PDCCH reception in symbols with LTE CRS REs NTT DOCOMO.

[15] R1-2207439 NR PDCCH reception in symbols with LTE CRS REs Ericsson

[16] R1-2207591 Considerations on NR PDCCH for DSS KT

# Appendix (Summary of the agreements)

## RAN1#109-e:

**Agreement**

**To evaluate the following options:**

* + Option-1-1: No NR-PDCCH-DMRS is transmitted for only the REs overlapping with LTE-CRS of the OFDM symbol, NR-PDCCH is punctured on REs colliding with LTE-CRS, NR-PDCCH must span at least 2 consecutive symbols with at least 1 symbol not overlapping with LTE-CRS
  + Option-1-2: No NR-PDCCH-DMRS is transmitted in any RE of the OFDM symbol, NR-PDCCH is transmitted on REs not colliding with LTE-CRS including the original DMRS, NR-PDCCH is punctured on REs colliding with LTE-CRS, NR-PDCCH must span at least 2 consecutive symbols with at least 1 symbol not overlapping with LTE-CRS
  + Option-2: NR-PDCCH or NR-PDCCH-DMRS is transmitted on REs not colliding with LTE-CRS, NR-PDCCH and NR-PDCCH-DMRS may or may not be punctured on REs colliding with LTE-CRS
    - No puncture is baseline (UE side)

**Observation**

For evaluations consider the following options:

**Option 1-1:**

* PDCCH and PDCCH DMRS mapping to REs: Legacy
* PDCCH REs overlapping with LTE CRS: Receiver punctures
* PDCCH DMRS REs overlapping with LTE CRS: All DMRS REs on overlapping symbol Not used for CE, or legacy pattern is assumed
* gNB transmits: Irrelevant what the gNB transmits on REs overlapping with the LTE CRS REs as indicated in the CRS RM pattern.
* Channel estimator: operate on clean symbol DMRS only, Legacy

**Option 1-2:**

* PDCCH and PDCCH DMRS mapping to REs: New PDCCH rate-matching
  + No PDCCH DMRS on the symbol overlapping with LTE CRS
* PDCCH REs overlapping with LTE CRS: Receiver punctures
* PDCCH DMRS REs overlapping with LTE CRS: Not expected
* Channel estimator (UE assumption): Operate on clean symbol DMRS only
* gNB transmits: Irrelevant what the gNB transmits on REs overlapping with the LTE CRS REs as indicated in the CRS RM pattern

**Option 2:**

* PDCCH and PDCCH DMRS mapping to REs: Legacy
* PDCCH REs overlapping with LTE CRS: Baseline: Process as legacy
* PDCCH DMRS REs overlapping with LTE CRS: Aware or unaware
* Channel estimator: Baseline: Process as legacy (Receiver does not puncture DMRS), Optional: Advanced receiver (Use the DMRS other than legacy behavior)
* gNB transmits:
  + Baseline: May puncture the PDCCH/PDCCH DMRS, or may superposition the two.
  + Optional: may puncture LTE CRS of Port#2&3.
  + Impact to LTE UEs should be considered if superposition is used.

Agreement

For evaluations consider the following list of scenarios:

Scenario#1A: 1 symbol CORESET, overlapped with CRS – Option 2 only

Scenario#2: 2 symbols CORESET, including 1 overlapping symbol and 1 clean symbol – Option 1-1/1-2/2

Scenario#3: 3 symbols CORESET, including 1 overlapping symbol and 2 clean symbols – Option 1-1/1-2/2

Agreement

LLS simulations assumptions, [] are optional:

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| --- | --- |
| **Parameters** | **Values** |
| Carrier frequency | 2 GHz |
| SCS | 15 kHz |
| Bandwidth | 20 MHz [5, 10 MHz], LTE bandwidth equal or smaller than NR |
| Channel model | TDL-C 300, [TDL-A 300] |
| Correlation | Low |
| Number of BS antennas | 4 Tx, (M,N,P,Mg,Ng;Mp,Np)= (1,2,2,1,1;1,1),  [2 Tx, (M,N,P,Mg,Ng;Mp,Np)= (1,1,2,1,1;1,1).] |
| Number of UE antennas | 2 Rx (M,N,P,Mg,Ng;Mp,Np)= (1,1,2,1,1;1,1) |
| DCI payload (excluding CRC) | 60 bits [50bits] |
| Interleaving | Non-Interleaved, [Interleaved] |
| Precoding | Precoder cycling per REG bundle |
| REG bundle size | 6 PRBs |
| CRS | single 4 port CRS pattern, [additional 4 port CRS pattern] |
| Channel estimation | practical – companies to report details |
| UE speed | 30 kmph [3kmph, 120 kmph, 350 kmph] |
| Power ratio of LTE-CRS RE/NR PDCCH RE, Power ratio of LTE-CRS RE/NR PDCCH-DMRS RE | Companies to report (if applicable) |

**Agreement**

SLS simulations assumptions, [] are optional:

|  |  |
| --- | --- |
| **Parameters** | **Values** |
| Carrier frequency | 2.1 GHz |
| SCS | 15 kHz |
| Simulation bandwidth | 20 MHz [5, 10 MHz]，same as that in LLS |
| BS antenna height | 25 m |
| UE height | 1.5m |
| TRP transmit power | 49 dBm 20 MHz |
| Scenario | Urban Macro (500m ISD), [Rma (1732m ISD)] |
| Device deployment | 80% indoor, 20% outdoor (Uma) [50% indoor,50% in-car (Rma)] |
| UE speeds | Indoor users: 3km/h |
| Outdoor users (in-car): 30 km/h |
| BS noise figure | 5 dB |
| BS antenna element gain | 8 dBi |
| UE noise figure | 9 dB |
| Thermal noise level | -174 dBm/Hz |
| Traffic geometry | Full Buffer |
| Macro sites | 19 |
| Downtilt | 102° or according to Scenario |
| Minimum BS to UE distance | 35m |
| KPI | Companies to report (e.g., total PDCCH capacity, PDCCH coverage/outage, Potential degradation of LTE, whether and how to achieve coexistence with legacy UEs) |
| Others | Companies to report (e.g., fraction of LTE UEs, fraction of Rel-18 DSS NR UEs, etc.). Companies to report considered baseline(s). Baseline(s) aim(s) to be comparable to the evaluated option(s) |