**3GPP TSG RAN WG1 Meeting #103-e R1-20xxxxx**

**E-meeting, October 26th - November 13th, 2020**

**Agenda Item: 8.8.2.1**

**Source: Moderator (China Telecom)**

**Title: [103-e-NR-CovEnh-04] Email discussion for PUSCH coverage enhancement**

**Document for: Discussion**

1. Introduction

In RAN #86 meeting, a new Rel-17 study item on NR coverage enhancements was approved [1]. The objective of this study item is to study potential coverage enhancement solutions for specific scenarios for both FR1 and FR2. The detailed objectives are as follows.

* *The target scenarios and services include*
  + *Urban (outdoor gNB serving indoor UEs) scenario, and rural scenario (including extreme long distance rural scenario) for FR1*
  + *Indoor scenario (indoor gNB serving indoor UEs), and urban/suburban scenario (including outdoor gNB serving outdoor UEs and outdoor gNB serving indoor UEs) for FR2.*
  + *TDD and FDD for FR1.*
  + *VoIP and eMBB service for FR1.*
  + *eMBB service as first priority and VoIP as second priority for FR2.*
  + *LPWA services and scenarios are not included.*
* *Identify baseline coverage performance for both DL and UL for the above scenarios and services based on link-level simulation*
  + *UL channels (including PUSCH and PUCCH) are prioritized for FR1.*
  + *Both DL and UL channels for FR2.*
* *Identify the performance target for coverage enhancement, and study the potential solutions for coverage enhancements for the above scenarios and services*
  + *The target channels include at least PUSCH/PUCCH*
  + *Study enhanced solutions, e.g., time domain/frequency domain/DM-RS enhancement (including DM-RS-less transmissions)*
  + *Study the additional enhanced solutions for FR2 if any*
  + *Evaluate the performance of the potential solutions based on link level simulation.*

This contribution is a summary of the following email discussion:

[103-e-NR-CovEnh-04] Email discussion for PUSCH coverage enhancement – Jianchi (CT)

* 1st check point: 10/29
* 2nd check point: 11/4
* 3rd check point: 11/10
* Last check point 11/12

1. Summary of potential solutions

## 2.1 Time domain based solutions

### 2.1.1 Enhancements on PUSCH repetition Type A

For enhancements on PUSCH repetition type A, there are three options:

* Option 1: Increase the maximum number of repetitions.
  + Support: HW, HiSi, CTC, Intel, CATT, Spreadtrum, OPPO, Sharp
* Option 2: The number of repetitions is counted on the basis of available UL slots.
  + Support: HW, HiSi, CTC, vivo, Intel, Samsung, ZTE, CATT, CMCC, Panasonic, OPPO, LG, Interdigital, NTT DOCOMO, ETRI
* Option 3: Flexible symbol resource allocation in different slots.
  + Support: CMCC, LG, ETRI

**Option 1: Increase the maximum number of repetitions.**

|  |  |
| --- | --- |
| **Supported companies** | HW, HiSi, CTC, Intel, CATT, Spreadtrum, OPPO, Sharp |
| **Companies have concerns** | **vivo**: If the actual number of repetitions is extended by simply extending the maximum number of repetitions, the actual number of repetition transmission may be not as expected.  **Sierra Wireless**: For the eMBB use cases, do not recommend specifying increased repetition for the PUSCH.  **Nokia/NSB**: The maximum number of repetitions for PUSCH repetition type A in release 15 is sufficient for FDD deployment. |
| **Potential spec. impact** | Increase the maximum number of repetitions for repetition type A, increase the entries of TDRA |

**Option 2: The number of repetitions is counted on the basis of available UL slots.**

|  |  |
| --- | --- |
| **Supported companies** | HW, HiSi, CTC, vivo, Intel, Samsung, ZTE, CATT, CMCC, Panasonic, OPPO, LG, Interdigital, NTT DOCOMO, ETRI |
| **Companies have concerns** | **Nokia/NSB**: The PUSCH repetition type B can be used to cope with the cancellation due to DL/UL collision in TDD deployment. Therefore, the consideration of counting repetition numbers based on non-consecutive slots for PUSCH repetition type A may not be needed. |
| **Potential spec. impact** | New mechanism to determine actual repetition times, the postponement rules for repetition type A should be supported |
| **Other considerations** | **Samsung** propose that a UE considers the slot format indicated by dynamic SFI for adjusting repetitions of a PUSCH transmission to include only UL symbols. |

* Option 3: Different symbol allocations applied in different slots.

|  |  |
| --- | --- |
| **Supported companies** | CMCC, LG, ETRI |
| **Potential spec. impact** | New mechanism to indicate UL symbols for each slot. |
| **Other considerations** | **ETRI** propose to study to indicate more than one SLIVs in a single UL grant. |

### 2.1.2 Enhancements on PUSCH repetition Type B

For enhancements on PUSCH repetition type B, there are three options:

* Option 1: Actual PUSCH transmission across the slot boundary and invalid symbols
  + Support: ZTE, CTC, Samsung, WILUS, ETRI
* Option 2: Actual PUSCH transmission across the slot boundary and invalid symbols, and the length of actual repetition larger than 14 symbols
  + Support: ZTE, CTC, Samsung, WILUS, Interdigital, NTT DOCOMO
* Option 3: RV enhancement
  + Support: vivo

**Option 1: Actual PUSCH transmission across the slot boundary and invalid symbols**

|  |  |
| --- | --- |
| **Supported companies** | ZTE, CTC, Samsung, WILUS, ETRI |
| **Companies have concerns** | **Nokia/NSB**: The enhancement on PUSCH repetition type B, e.g. actual repetition across the slot boundary, or the length of actual repetition larger than 14 symbols, is in the same category and should be discussed together with TB processing over multiple slots for PUSCH. The PUSCH coverage enhancement based on PUSCH repetition type B framework should be avoided. |
| **Potential spec. impact** | UE behaviour on handling of across slot boundary and invalid symbols, TBS determination, DM-RS pattern and DCI indication. |
| **Other considerations** | **Intel**: Enhancement on PUSCH repetition type B in time domain needs to be carefully studied in WI phase with considerations of impacts on UE implementation. |

**Option 2: Actual PUSCH transmission across the slot boundary and invalid symbols, and the length of actual repetition larger than 14 symbols**

|  |  |
| --- | --- |
| **Supported companies** | ZTE, CTC, Samsung, WILUS, Interdigital, NTT DOCOMO |
| **Companies have concerns** | **Nokia/NSB**: The enhancement on PUSCH repetition type B, e.g. actual repetition across the slot boundary, or the length of actual repetition larger than 14 symbols, is in the same category and should be discussed together with TB processing over multiple slots for PUSCH. The PUSCH coverage enhancement based on PUSCH repetition type B framework should be avoided.  **Spreadtrum**: don’t support increasing maximum number of symbols for PUSCH. |
| **Potential spec. impact** | TBS determination, DM-RS pattern, DCI indication, SLIV table, hopping rules |
| **Other considerations** | **WILUS**: If across slot boundaries + actual repetition larger than 14 symbols are adopted, Additional consideration may be required for the hopping boundary determination    Option 1: Slot boundary  Option 2: Nominal repetition boundary  Option 3: Aggregated actual repetition boundary  **Intel**: Enhancement on PUSCH repetition type B in time domain needs to be carefully studied in WI phase with considerations of impacts on UE implementation. |

**Option 3: Single TB, transmitted in parts over multiple actual repetition**

|  |  |
| --- | --- |
| **Supported companies** | vivo |
| **Potential spec. impact** | enhanced or new rules of determining RV for each repetition, enhanced or new segment rules of actual repetitions. |

### 2.1.3 TB processing over multi-slot PUSCH

For TB processing over multi-slot PUSCH, there are two options:

* Option 1: TBS is determined based on single slot, transmitted in parts over multiple slots.
  + Support: Interdigital
* Option 2: TBS is determined based on multiple slots.
  + Support: IITH, IITM, CEWIT, Reliance Jio, Tejas Networks, Intel, CTC, LG, Qualcomm, Panasonic

|  |  |
| --- | --- |
| **Supported companies** | vivo, IITH, IITM, CEWIT, Reliance Jio, Tejas Networks, Intel, CTC, LG, Interdigital, Qualcomm, Panasonic |
| **Potential spec. impact** | Uniform TDRA or start symbol and length, TBS and DMRS pattern, UE behaviour and related signalling. |
| **Other considerations** | **vivo**: For multi-slot PUSCH, applying the same TDRA over multiple slots would result in the discontinuous resource and inflexible allocation, the available resources cannot be fully utilized.  **CTC**:   * Option 1: TBS is determined based on single slot, transmitted in parts over multiple slots. * Option 2: TBS is determined based on multiple slots.   + Option 2a: different RV version is transmitted in each slot.   + Option 2b: different segment is transmitted in each slot.   **Nokia/NSB**: There is a tradeoff between the time domain diversity gain from PUSCH repetition and the low coding rate gain brought by the potential TB processing over multiple slots. The applicability of this solution in TDD deployment is limited. |

### 2.1.4 OCC spreading based repetition

**ZTE, Xiaomi**: OCC spreading based PUSCH can be considered for NR coverage enhancement. Orthogonal code division multiplexing among different UEs can be considered in case of repetitions



### 2.1.5 Symbol-level repetition/combing

**Panasonic**: Symbol-level repetition could be considered as one of cross-slot channel estimation techniques combined with TB processing over multi-slot PUSCH. The same OFDM symbol is repeated in N consecutive symbols, where N is the number of repetitions. This structure is also suitable to perform symbol-level combining.



**LG**: Symbol-level combining should be studied to enhance PUSCH coverage. Symbol-level combining can be supported by applying the same RV value during a bundle of PUSCH slots.

### 2.1.6 TB interleaving

**Sierra Wireless**: Recommend that gaps between repeats be specified as a Rel 17 Coverage enhancement solution.

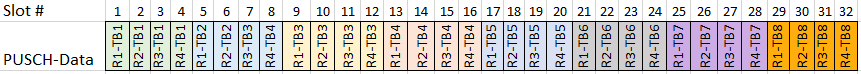


Figure 2a: Legacy scheduling (i.e. without gaps)

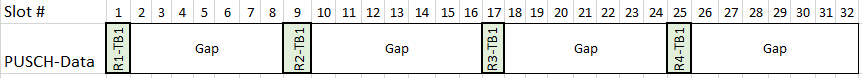


Figure 2b: No TBs scheduled within the gaps



Figure 2c: TBs scheduled within the gaps

Figure 2a illustrates how multiple TBs are in scheduled with repeats in legacy Rel 16 where each repeat is scheduled over contiguous slots. Figure 2b illustrates how a single TB is scheduled with a gap of 7 slots. Figure 2c illustrates the scheduling where the gap is filled with TBs #2-8. TBs #2-8 could be TBs for other users or for the same user as TB #1. If the TBs are all for the same user, this scheduling pattern provides the same data rate as if no gaps are used (i.e. figure 2a and 2c have the same data rate for that user). Allowing the gaps to be filled with TBs for other users, improves the gNB’s scheduling flexibility which will result in lower latency for other users and improved capacity.

### 2.1.7 Early termination of PUSCH repetitions

|  |  |
| --- | --- |
| **Supported companies** | ZTE, CMCC, OPPO |
| **Companies have concerns** | **Nokia/NSB**: The potential advantage of introducing early termination of PUSCH repetition is unclear. |
| **Potential spec. impact** | Mechanism and signaling of early termination. |
| **Other considerations** | **ZTE, Panasonic**: DFI specified in Rel.16 NR-U for explicit ACK can be used as the starting point |

## 2.2 Frequency domain based solutions

### 2.2.1 Enhancements on inter-slot frequency hopping

* Inter-slot frequency hopping with more frequency offsets/ more frequency hopping positions
  + Support: HW, HiSi, Xiaomi, vivo, ZTE, NEC, Sony, NTT DOCOMO, CTC, Spreadtrum

|  |  |
| --- | --- |
| **Supported companies** | HW, HiSi, Xiaomi, vivo, ZTE, NEC, Sony, NTT DOCOMO, CTC, Spreadtrum |
| **Companies have concerns** | **Intel**: Increasing the number of frequency hops from 2 to 4 for inter-slot frequency hopping may not be supported for NR coverage enhancement WI. |
| **Potential spec. impact** | Frequency hopping pattern and related signalling (RRC, DCI indication). |
| **Other considerations** | **CATT**: The suitable number of frequency hopping and the number of hopping offset candidates should be firstly determined, which may be dependent with BWP bandwidth. Then, it should be further studied how to flexibly indicate the hopping.  **Sony**: For PUSCH frequency hopping, the gNB can dynamically adapt the frequency hopping pattern, based on which hops are more effective. |

### 2.2.2 Inter-slot frequency hopping with inter-slot bundling

* Inter-slot frequency hopping with inter-slot bundling to enable cross-slot channel estimation
  + Support: ZTE, Intel, CTC, NEC, Samsung, LG, Panasonic, interdigital

|  |  |
| --- | --- |
| **Supported companies** | ZTE, Intel, CTC, NEC, Samsung, LG, Panasonic, interdigital |
| **Companies have concerns** | **CATT**: Cross-slot channel estimation should be well studied before supporting this mechanism. |
| **Potential spec. impact** | Frequency domain hopping offset, time domain hopping interval and the related signalling, power consistency and the phase continuity within one bundle should be preserved. |
| **Other considerations** | **Nokia/NSB**: whether this solution should be supported or not depending on the outcome of cross-slot channel estimation solution. |

### 2.2.3 Enhancements on frequency hopping for PUSCH repetition type B

|  |  |
| --- | --- |
| **Supported companies** | CATT |
| **Companies have concerns** | **vivo**: Intra-repetition frequency hopping for PUSCH repetition type B should be deprioritized.  **Spreadtrum**: Postpone the discussion on enhancements on frequency hopping for PUSCH repetition type B. |

### 2.2.4 Sub-PRB transmission

* Sub-PRB transmission with multi-slot aggregation for VoIP
  + Support: CTC, Sony, LG, NTT DOCOMO, Sierra Wireless, Samsung

|  |  |
| --- | --- |
| **Supported companies** | CTC, Sony, LG, NTT DOCOMO, Sierra Wireless, Samsung |
| **Companies have concerns** | **vivo**: sub-PRB transmission with single TB sized for multiple slots and transmitted over multiple slots suffers higher complexity and latency. Furthermore, sub-PRB transmission requires significant work on specification. Thus, sub-PRB transmission is not supported for PUSCH coverage enhancement.  **CATT**: It can be foreseen that specifying Sub-PRB resource allocation requires heavy standard work, including sub-PRB pattern definition, FDRA/TDRA indication, hopping pattern within/between the PRBs, DMRS design, coexistence with legacy UEs, etc. Sub-PRB resource allocation may be supported, but the motivation needs more justification.  **Intel**: Depending on coverage enhancement target for VoIP under various deployment scenarios in FR1 and FR2, further study is needed to conclude whether sub-PRB based resource allocation can be considered for PUSCH coverage enhancement.  **Spreadtrum**: Too much specification efforts are needed. |
| **Potential spec. impact** | Sub-PRB pattern definition, FDRA/TDRA indication, hopping pattern within/between the PRBs, DMRS design, TBS determination, UE behaviour and related signalling. |
| **Other considerations** | **Sierra Wireless**: Recommend the 2 Tone Pi/2 BPSK (LTE-M) scheme be specified to improve coverage for VoIP. LTE-M and NB-IOT both support a near zero PAPR modulation schemes using the sub-PRB technique (**2 tone DTF-spread pi/2 BPSK** for LTE-M and single tone pi/2 BPSK for NB-IOT). The near-zero PAPR sub-PRB based modulation doesn’t increase coverage directly but instead reduce the need to define MPR and A-MPR values which would then require the UE to transmit at a higher power which increases coverage.  **CTC**:   * Option 1: TBS is determined based on sub-PRB and single slot. * Option 2: TBS is determined based on sub-PRB and multiple slots.   For option 1, sub-PRB transmission can be in conjunction with repetition. For option 2, the basic principle is similar with TB processing over multi-slot PUSCH, while sub-PRB transmission can further benefit from PSD boosting.  **Samsung**: frequency domain resource allocation, power control, DMRS related may or may not be needed, no spec impact on TBS determination.  **Nokia/NSB**: There is a trade-off between Tx power per subcarrier vs SNR gain, which should be carefully considered. |

### 2.2.5 Enhancements on Intra-slot frequency hopping

|  |  |
| --- | --- |
| **Supported companies** | CTC, Spreadtrum, Nokia/NSB |
| **Companies have concerns** | **Xiaomi**: from the perspective of balancing complexity and performance gain, intra-slot frequency hopping should not to be supported. |
| **Potential spec. impact** | Frequency hopping pattern and related signalling (RRC, DCI indication). |
| **Other considerations** | **Nokia/NSB:** intra-frequency hopping with 3 hops and DMRS sharing. |

## 2.3 DM-RS enhancements

### 2.3.1 Cross-slot channel estimation

* Cross slot channel estimation
  + Support: HW, HiSi, Xiaomi, ZTE, ETRI, CTC, CMCC, NEC, Samsung, OPPO, Sharp, LG, Ericsson, Interdigital, NTT DOCOMO, Qualcomm, Intel

|  |  |
| --- | --- |
| **Supported companies** | HW, HiSi, Xiaomi, ZTE, ETRI, CTC, CMCC, NEC, Samsung, OPPO, Sharp, LG, Ericsson, Interdigital, NTT DOCOMO, Qualcomm, Intel |
| **Potential spec. impact** | Power consistency and phase continuity should be preserved, DMRS placement in special slot, DMRS configuration. |
| **Other considerations** | **Vivo:** To guarantee phase and power continuity, potential solution is to indicate UE the continuity/spatial relation among slots or transmissions implicitly or explicitly.  **ZTE**: Further study whether phase continuity can be kept across slot boundary.  **CATT**: It need to be further studied whether UE power un-consistency exists due to potential reasons like the updated pathloss measurement or modulation-order-dependent power reduction.  **NEC**: The granularity of symbol number within one slot may not be suitable for cross channel estimation among multiple slots. To overcome this issue, different number of DMRS symbol in different slot could be studied.  **Panasonic**: In order to support cross-slot channel estimation, RAN1 asks to RAN4 in what condition phase continuity can be kept. If cross-slot/cross-repetition channel estimation is supported, adaptive DMRS transmission, in which DMRS configuration can be different among slots or repetition could also be considered.  **Interdigital, Xiaomi**: Support DMRS placement in a special slot which can be bundled with DMRS in the adjacent uplink slot.  **NTT DOCOMO:** Cross-slot channel estimation with non-consecutive PUSCH slots should be also considered for the performance evaluation. |

### 2.3.2 Lower DMRS density

For lower DM-RS density, there are two options:

* Option 1: lower density in time domain, e.g., DMRS sharing among multiple PUSCH transmissions
  + Support: HW, HiSi, Spreadtrum, OPPO, Sharp, Nokia, NSB, xiaomi
* Option 2: lower density in frequency domain
  + ZTE

|  |  |
| --- | --- |
| **Supported companies** | HW, HiSi, Spreadtrum, OPPO, Sharp, Nokia, NSB, ZTE, xiaomi |
| **Companies have concerns** | **CATT**: DMRS enhancement is more related to MIMO enhancement, which may lead to heavy cross-topic specification work. It is suggested to justify the benefit of the DMRS density enhancement firstly.  **Intel**: Lower DMRS density in time domain is not supported for PUSCH coverage enhancement. |
| **Potential spec. impact** | DM-RS pattern and related signaling. |

### 2.3.3 Higher DMRS density

|  |  |
| --- | --- |
| **Supported companies** | **CTC:** 1-comb DMRS (DM-RS with single port spans to occupy the whole DM-RS symbol)  **NTT DOCOMO**: Denser DM-RS mapping (e.g. 3 additional DMRS for 2 symbol DMRS) |
| **Companies have concerns** | **Intel, LG**: Higher DMRS density in time domain may not be needed for PUSCH coverage enhancement.  **CATT**: DMRS enhancement is more related to MIMO enhancement, which may lead to heavy cross-topic specification work. It is suggested to justify the benefit of the DMRS density enhancement firstly. |
| **Potential spec. impact** | DM-RS design and TBS determination. |

### 2.3.4 Adaptive DMRS configuration

|  |  |
| --- | --- |
| **Supported companies** | CMCC, Sony, Qualcomm |
| **Other considerations** | **Qualcomm** propose 2 options to enable efficient DMRS adaptation:   * **Option 1:** Dynamic MAC-CE based activation + complementary DCI based selection of one of the activated DMRS configuration options. * **Option 2:** Single active DMRS configuration option that is dynamically activated by MAC-CE.   **Corresponding potential spec.** **impact**:  DMRS configurations, mechanism of DMRS configuration activation and selection. |

### 2.3.5 DM-RS balancing among frequency hops

**Nokia/NSB**: When PUSCH repetition type A and intra-slot frequency hopping are both applied, if an odd number of DMRS per slots is configured then the actual number of DMRS symbols per hop is not the same. This may lead to deterministic channel estimation accuracy differences across hops. This aspect should be considered when discussing DMRS enhancement solutions.

## 2.4 Power-domain based solutions

### 2.4.1 Waveform design to optimize MPR/A-MPR

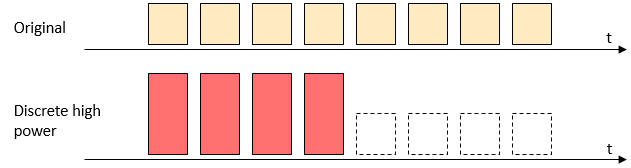
|  |  |
| --- | --- |
| **Supported companies** | Interdigital, Qualcomm, Nokia, NSB |
| **Companies have concerns** | **CATT**: In RAN4, MPR/A-MPR is defined to put a requirement on range of UE power reduction. It only restricts the maximum reduced power, but the actual power reduction is up to UE implementation. The benefit for new waveform is not so clear, since the gain for optimizing power reduction is unclear and hard to be quantified. Anyway, RAN1 should firstly ask RAN4 the feasibility and availability, if it is indeed interesting and attractive. |
| **Other considerations** | **Interdigital**: For example, the gNB can determine based on e.g. uplink reference signals or based on power head room report if the UE needs more transmission power to achieve the performance target. The gNB can then indicate to the UE to use PAPR reduction techniques in the subsequent uplink transmissions.  **Qualcomm**: Consider tone reservation principle for DFT-s-OFDM and CP-OFDM waveforms to further reduce PAPR.  **Nokia/NSB**:The FDSS with spectral extension for QPSK is considered as potential solution to reduce MPR and to improve UL PUSCH coverage. |

### 2.4.2 Power boosting for pi/2 BPSK

**IITH, IITM, CEWIT, Reliance Jio, Tejas Networks**: Make pi/2 BPSK power boosting a function of the UL duty cycle. Send LS to RAN4 to study the feasibility of power boosting for pi/2 BPSK modulation beyond 26 dBm as a function of the UL duty cycle.

### 2.4.3 FDD high power UE

**HW/HiSi**: The most effective way to increase the SNR is directly using a higher instant output power at some specific slots while zero power is allocated to other slots of the FDD duration, thus maintaining the same total transmission power of all slots in the FDD duration and satisfying the SAR requirement.



**Concerns:**

CATT, OPPO, Sony: Power domain based enhancement should be carefully studied by RAN4 before starting any specification work in RAN1.

## 2.5 Spatial-domain based solutions

### 2.5.1 Multiple layer PUSCH transmission with DFT-S-OFDM

**Ericsson**:

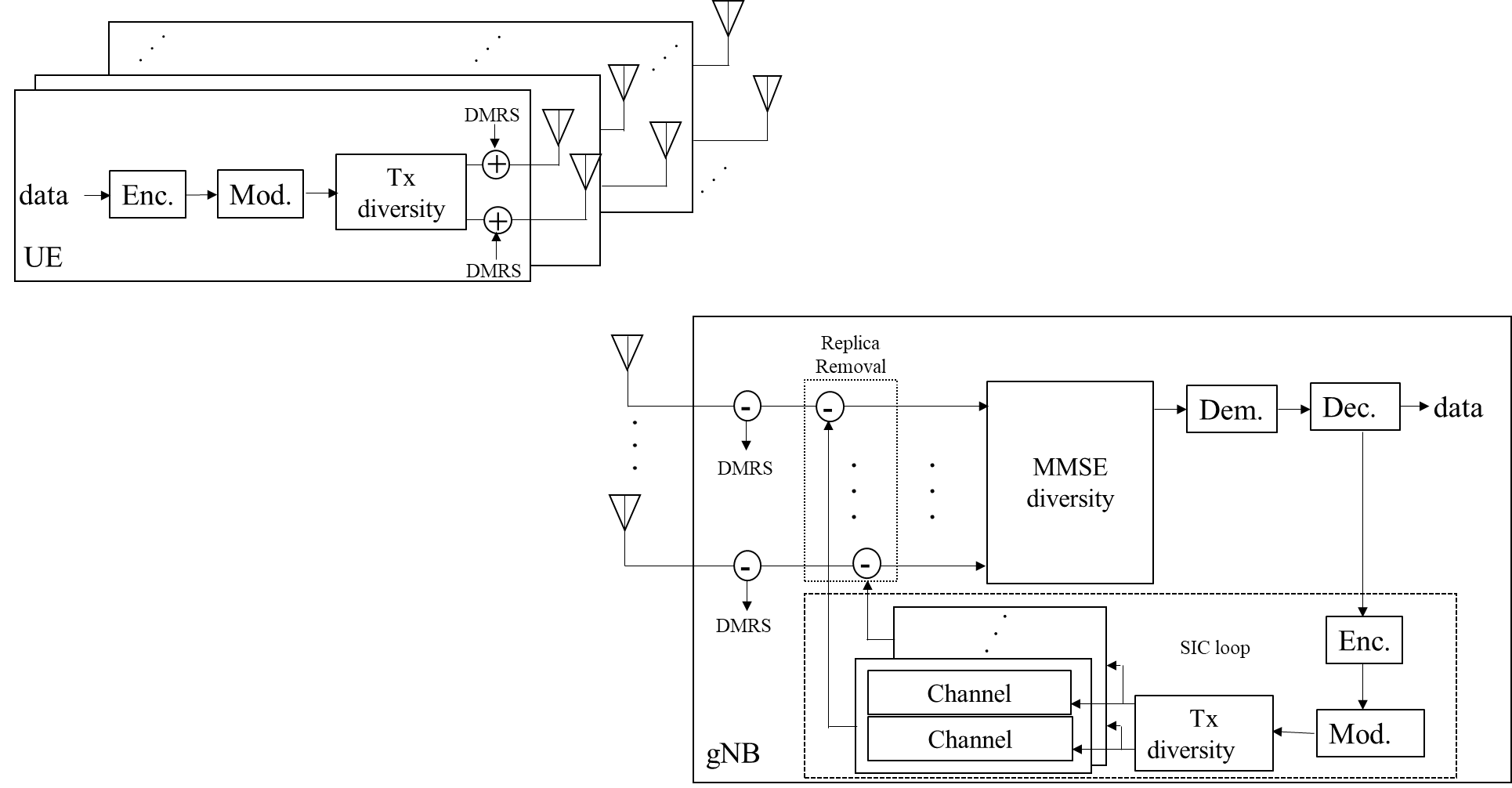
* Non-coherent and partially coherent UE’s PAPR or cubic metric (CM) of multiple layer PUSCH transmission is not higher than 1-layer PUSCH transmission by coherent UE.
* Multiple layer PUSCH transmission with DFT-S-OFDM can improve PUSCH cell coverage.
* Multiple layer transmission is especially beneficial in the non-coherent UEs that are those most used in real deployment, since multi-layer transmission provides more power in these UEs.
  + Pure rank 1 transmission tends to be infrequent even for UEs in the poorest channel conditions when few gNB antennas are used.
  + When massive MIMO gNBs are used, rank 1 is almost never selected.

**Concerns**:

**CATT**: For multi-layer DFT-s-OFDM, the motivation is not so clear, since higher ranks are usually chosen only when the channel quality is good enough. In this case, the UL coverage is not the bottleneck, and the UE transmission power is not necessary to be high. Then, PAPR does not cause serious issue even if CP-OFDM waveform is applied, which is mandatorily supported by all NR UEs. In this case, CP-OFDM can be applied for multi-layer PUSCH transmission.

### 2.5.2 Open-loop/closed loop Tx diversity

**NICT**: The use of DFT-s-OFDM with Tx diversity should be one of the approaches for coverage enhancement.



**Mitsubishi Electric**:Alamouti-based transmit diversity is supported for PUSCH with DFT-s-OFDM.

**OPPO**: In order to harvest the spatial diversity gain, different PUSCH spatial filter parameters and different antenna ports can be applied for different PUSCH slots.

## 2.6 Others

### 2.6.1 Dynamic PUSCH waveform adaptation

**Qualcomm**: To enable efficient waveform adaptation in 5G NR, a new signaling mechanism for dynamic waveform reconfiguration is required.

* **Option 1:** Dynamic MAC-CE based activation of the active MCS table. Different RRC configured MCS tables are associated with different waveforms and the activated MCS table provides an implicit indication of the associated waveform.
* **Option 2:** A new hybrid MCS table will be defined as a combination of MCSs from the existing MCS tables for DFT-S-OFDM and CP-OFDM transmission schemes. PUSCH MSC idx signaled in a scheduling DCI (scheduled grant) or configured under *ConfiguredGrantConfig* in case of a configured grant for PUSCH will be used as an implicit signaling for the transmission scheme.

**Potential specification impact**:

For Option 1, MCS table configurations, mechanism for MCS table activation/selection based on MAC-CE signaling

For Option 2, new hybrid MCS table needs to be defined.

### 2.6.2 Coverage enhancement for voice

**Ericsson**:

* Indicate to CT1 and SA4 that 2KB SIP message sizes may impact VoNR coverage or setup latency in arduous coverage scenarios and ask if SigComP functionality can be supported to reduce SIP message overhead.
* Ask CT1/SA4 what SIP message packet sizes and arrival rates can be expected.

1. Proposals (1st round)

In RAN1 #102-e, following agreements have been achieved:

|  |
| --- |
| **Agreements:**   * Study following power domain based solution for PUSCH enhancements   + Waveform design to optimize MPR/A-MPR   + [FDD high power UE]   + Power boosting for pi/2 BPSK   Note: if a LS to RAN4 (for the last two bullets) is deemed necessary, target sending the LS in the 1st week of RAN1#103-e. |

* Q1: Is it necessary to send LS to RAN4?
* Q2: It is expected to receive reply LS from RAN4 during this meeting? If no, how to make conclusions in RAN1?

Companies are invited to answer the above questions.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Sierra Wireless | Its unclear what the question(s) to RAN4 will be thus there is no need to send LS to RAN4. |
|  |  |
|  |  |

//Proposal 1-13: Conclusions or observations on details and specification impacts for each enhanced solution

Proposal 1: Capture the followings into the TR

* Enhancements on PUSCH repetition type A were studied from several aspects, including increasing the maximum number of repetitions, the number of repetitions counted on the basis of available UL slots and flexible symbol resource allocation in different slots.
* Potential specification impacts of enhancements on PUSCH repetition type A include:
  + Increase the entries of TDRA, mechanism to determine actual repetition times, mechanism to indicate UL symbols for each slot.

Companies are invited to provide views on the above proposal.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Sierra Wireless | Consider making the sentence past tense (this goes for all the proposal to the TR).  Enhancements on PUSCH repetition type A were studied from several aspects, including increasing the maximum number of repetitions, …. |
|  |  |
|  |  |

Proposal 2: Capture the followings into the TR

* Enhancements on PUSCH repetition type B are studied from several aspects, including actual PUSCH transmission across the slot boundary/invalid symbols and the length of actual repetition larger than 14 symbols.
* Potential specification impacts of enhancements on PUSCH repetition type B include:
  + TBS determination, DM-RS pattern, DCI indication, SLIV table, hopping rules.

Companies are invited to provide views on the above proposal.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
|  |  |
|  |  |
|  |  |

Proposal 3: Capture the followings into the TR

* TB processing over multi-slot PUSCH is studied from several aspects, including TBS determined based on single slot, transmitted in parts over multiple slots and TBS determined based on multiple slots.
* Potential specification impacts of TB processing over multi-slot PUSCH include:
  + Time domain resource allocation, TBS determination, DM-RS pattern, RV determination.

Companies are invited to provide views on the above proposal.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Sierra Wireless | Its not clear what you mean with TBS – perhaps I think you instead mean Codeword. Also, for the case where the codewords are coded across multiple slots, the transmission still occurs across multiple slots where for TDD there may be gaps. Give this the following update is preferred:   * TB processing over multi-slot PUSCH was studied from several aspects, including codewords determined based on single slot, transmitted in parts over multiple slots and codewords determined based on multiple slots, transmitted over multiple slots with and without gaps. |
|  |  |
|  |  |

Proposal 4: Capture the followings into the TR

* Enhancements on inter-slot frequency hopping are studied from several aspects, including more frequency offsets and more frequency hopping positions.
* Potential specification impacts of enhancements on inter-slot frequency hopping include:
  + Frequency domain hopping offsets, DM-RS pattern, TBS determination.

Companies are invited to provide views on the above proposal.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
|  |  |
|  |  |
|  |  |

Proposal 5: Capture the followings into the TR

* Potential specification impacts of inter-slot frequency hopping with inter-slot bundling to enable cross-slot channel estimation include:
  + Frequency domain hopping offset, time domain hopping interval, power consistency and the phase continuity within one bundle.

Companies are invited to provide views on the above proposal.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
|  |  |
|  |  |
|  |  |

Proposal 6: Capture the followings into the TR

* Sub-PRB transmission is studied from several aspects, including number of tones, sub-PRB transmission with single slot and sub-PRB transmission with multi-slot aggregation.
* Potential specification impacts of sub-PRB transmission include:
  + Frequency domain resource allocation, time domain resource allocation, TBS determination, DM-RS pattern, RV determination, hopping pattern within/between the PRBs

Companies are invited to provide views on the above proposal.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
|  |  |
|  |  |
|  |  |

Proposal 7: Capture the followings into the TR

* Enhancements on intra-slot frequency hopping are studied from several aspects, including more frequency offsets, more frequency hopping positions and DM-RS sharing among multiple PUSCH transmissions.
* Potential specification impacts of enhancements on intra-slot frequency hopping include:
  + Frequency domain hopping offsets, DM-RS pattern, TBS determination, power consistency and phase continuity.

Companies are invited to provide views on the above proposal.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
|  |  |
|  |  |
|  |  |

Proposal 8: Capture the followings into the TR

* Potential specification impacts of cross-slot channel estimation include:
  + Power consistency and phase continuity, DM-RS placement in special slot and DM-RS configuration.

Companies are invited to provide views on the above proposal.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
|  |  |
|  |  |
|  |  |

Proposal 9: Capture the followings into the TR

* Lower DM-RS density in time domain is studied, including DM-RS sharing among multiple PUSCH transmissions.
* Potential specification impacts of DM-RS sharing among multiple PUSCH transmissions include:
  + DM-RS pattern and configuration, power consistency and phase continuity.

Companies are invited to provide views on the above proposal.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
|  |  |
|  |  |
|  |  |

Proposal 10: Capture the followings into the TR

* Higher DM-RS density is studied, including 1-comb DM-RS and additional DM-RS symbol position.
* Potential specification impacts of higher DM-RS density include:
  + DM-RS design, DM-RS position and TBS determination.

Companies are invited to provide views on the above proposal.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
|  |  |
|  |  |
|  |  |

Proposal 11: Capture the followings into the TR

* Potential specification impacts of adaptive DM-RS configuration include:
  + Related signaling design.

Companies are invited to provide views on the above proposal.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
|  |  |
|  |  |
|  |  |

Proposal 12: Capture the followings into the TR

* DM-RS balancing among frequency hops is studied. Potential specification impacts include related signaling design.

Companies are invited to provide views on the above proposal.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
|  |  |
|  |  |
|  |  |

Proposal 13: Capture the followings into the TR

* UE transmit waveform design to reduce MPR is studies from several aspects, including tone reservation and FDSS with spectral extension for QPSK.
* Potential specification impacts include
  + UE transmit waveform design, RF requirements.

Companies are invited to provide views on the above proposal.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
|  |  |
|  |  |
|  |  |

Companies are invited to provide views on the others solutions, if any.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
|  |  |
|  |  |
|  |  |

1. Proposals on hold

// Observations from evaluation results (start discussion from second week)

//Companies are encouraged to submit/update simulation results as early as possible.

Proposal: Capture following observations into the TR.

Observation 1:

* Five sources evaluate the performance of enhancements on PUSCH repetition type A.
  + Three sources show 1.0~6.8 dB required SNR gain when the actual number of repetition is increased for VoIP for TDD, compared to Rel-16 PUSCH repetition type A.
  + Two sources show 2.0~6.4 dB required SNR gain when the actual number of repetition is increased for eMBB for TDD, compared to Rel-16 PUSCH repetition type A.
  + One source shows -1.6~0.4 dB required SNR gain depending on the scenarios when the maximum number of repetitions is increased for eMBB for FDD, compared to Rel-16 PUSCH repetition type A.

Observation 2:

* Four sources evaluate the performance of enhancements on PUSCH repetition type B.
  + Three sources show 0.2~2.0 dB required SNR gain when the actual PUSCH transmission can across the slot boundary and the length of actual repetition can be larger than 14 symbols for VoIP, compared to Rel-16 PUSCH repetition type B.
  + One sources shows 0.33~0.38 dB required SNR gain when the actual PUSCH transmission can across the slot boundary and the length of actual repetition can be larger than 14 symbols for eMBB, compared to Rel-16 PUSCH repetition type B.
  + One source shows around 2.0 dB required SNR gain for RV enhancement for eMBB, compared to Rel-16 PUSCH repetition type B.

Observation 3:

* Seven sources evaluate the performance of TB processing over multi-slot PUSCH.
  + Three sources show 0.2~2.0 dB required SNR gain when TBS is determined based on multi-slot for VoIP, compared to TB is determined based on single slot in Rel-16.
  + Five sources show 0~2.7 dB required SNR gain when TBS is determined based on multi-slot for eMBB, compared to TB is determined based on single slot in Rel-16.
  + One source shows 0.4~2.0 dB required SNR gain depending on the number of aggregated slots and modulation when TBS is determined based on multi-slot for VoIP, compared to TB is determined based on single slot in Rel-16.
  + One source shows 0~1.75 dB required SNR gain depending on the number of aggregated slots and modulation when TBS is determined based on multi-slot for eMBB, compared to TB is determined based on single slot in Rel-16.

Observation 4:

* Six sources evaluate the performance of inter-slot frequency hopping with more frequency offsets/ more frequency hopping positions.
  + Four sources show 0.3~1.5 dB required SNR gain for inter-slot frequency hopping with more frequency offsets/ more frequency hopping positions for eMBB, compared to Rel-16 inter frequency hopping.
  + One source shows 0~1.3 dB required SNR gain depending on the scenarios or whether cross-slot channel estimation is adopted for inter-slot frequency hopping with more frequency offsets/ more frequency hopping positions for eMBB, compared to Rel-16 inter frequency hopping.
  + One source shows no gain for inter-slot frequency hopping with more frequency offsets/ more frequency hopping positions for eMBB, compared to Rel-16 inter frequency hopping.

Observation 5:

* Five sources evaluate the performance of inter-slot frequency hopping with inter-slot bundling and cross-slot channel estimation.
  + Two sources show 0.5~2.5 dB required SNR gain for inter-slot frequency hopping with inter-slot bundling for VoIP depending on bundle size, DM-RS configurations and frequency band, compared to Rel-16 inter-slot frequency hopping.
  + Three sources show 0.5~1.3 dB required SNR gain for inter-slot frequency hopping with inter-slot bundling for eMBB depending on bundle size, compared to Rel-16 inter-slot frequency hopping.

Observation 6:

* Four sources evaluate the performance of sub-PRB transmission with multi-slot aggregation.
  + One source shows around 0.8 dB required SNR gain for sub-PRB transmission with 6 tones for VoIP, compared to Rel-16 PRB-based transmission.
  + One source shows 5.6/8.5 dB performance gain for sub-PRB transmission with 6 tones for VoIP/eMBB, respectively, compared to Rel-16 PRB-based transmission.
  + One source shows up to 5 dB performance gain for sub-PRB transmission with 2 tones for VoIP, compared to Rel-16 PRB-based transmission.
  + One source shows no gain for sub-PRB transmission for VoIP, compared to Rel-16 PRB-based transmission.

Observation 7:

* Fourteen sources evaluate the performance of cross-slot channel estimation.
  + Eleven sources show 0.4~2 dB required SNR gain for cross-slot channel estimation for eMBB depending on bundle size, compared to PUSCH transmission without cross-slot channel estimation.
  + One source shows 2~3 dB required SNR gain for cross-slot channel estimation w/ frequency hopping for eMBB, compared to PUSCH transmission without cross-slot channel estimation.
  + Two sources show 0.85~1.3 dB required SNR gain for cross-slot channel estimation for VoIP depending on bundle size and frequency band, compared to PUSCH transmission without cross-slot channel estimation.

Observation 8:

* Three sources evaluate the performance of lower DM-RS density.
  + One source shows around 1.4 dB required SNR gain for lower DM-RS density in time domain with cross-slot channel estimation for eMBB, compared to Rel-16 DM-RS density.
  + One source shows around 1.0 dB required SNR gain for lower DM-RS density in frequency domain for eMBB, compared to Rel-16 DM-RS density.
  + One source shows around 0.2 dB required SNR loss for lower DM-RS density in time domain for eMBB, compared to Rel-16 DM-RS density.

Observation 9:

* Three sources evaluate the performance of higher DM-RS density.
  + One source shows 0.5~1.5 dB required SNR gain for 1-comb DM-RS for eMBB, compared to Rel-16 DM-RS density.
  + One source shows around 1.0 dB required SNR gain for additional DM-RS symbol position for VoIP, compared to Rel-16 DM-RS density.
  + One source shows around 0.05 dB required SNR loss for higher DM-RS density in time domain for eMBB, compared to Rel-16 DM-RS density.

Observation 10:

* One source evaluates the performance of adaptive DM-RS configuration and shows around 1.7 dB required SNR gain compared to Rel-16 DM-RS density.
* One source evaluates the performance of enhanced intra-slot frequency hopping with more frequency offsets/ more frequency hopping positions and shows around 1.8 dB required SNR gain for VoIP and 0.4 dB required SNR gain for eMBB, compared to Rel-16 intra-slot frequency hopping.
* One source evaluates the performance of power boosting for pi/2 BPSK and shows around 3 dB gain for UL duty cycle less than 50% and around 6 dB gain for UL duty cycle less than 25%.
* One source evaluates the performance of dynamic switching between DFT-S-OFDM and CP-OFDM and shows 1~1.5 dB gain, compared to semi-static switching between DFT-S-OFDM and CP-OFDM.
* One source evaluates the performance of UE transmit waveform design to reduce MPR and shows 1.0~1.5 dB gain, compared to Rel-16 DFT-S-OFDM and CP-OFDM.
* One source evaluates the performance of symbol level repetition and shows around 0.4 dB required SNR gain, compared to Rel-16 PUSCH repetition type A.

// Conclusions or recommendations on the enhanced solutions (to be discussed after Nov. 6)

Proposal: Capture the followings into the TR

* Enhancements on PUSCH repetition type A is beneficial for PUSCH coverage enhancements for TDD. It is recommended to support enhancements on PUSCH repetition type A in Rel-17.
  + Increasing the maximum number of repetitions.
  + The number of repetitions counted on the basis of available UL slots.
* Enhancements on PUSCH repetition type B is beneficial for PUSCH coverage enhancements. It is recommended to support enhancements on PUSCH repetition type B in Rel-17.
  + Actual PUSCH transmission across the slot boundary/invalid symbols.
  + The length of actual repetition larger than 14 symbols.
* TB processing over multi-slot PUSCH is beneficial for PUSCH coverage enhancements. It is recommended to support TB processing over multi-slot PUSCH in Rel-17.
  + TBS determined based on multiple slots
* Enhancements on inter-slot frequency hopping is beneficial for PUSCH coverage enhancements. It is recommended to support inter-slot frequency hopping with more frequency offsets/ more frequency hopping positions for PUSCH in Rel-17.
* Inter-slot frequency hopping with inter-slot bundling to enable cross-slot channel estimation is beneficial for PUSCH coverage enhancements. It is recommended to support inter-slot frequency hopping with inter-slot bundling to enable cross-slot channel estimation for PUSCH in Rel-17.
* Sub-PRB transmission with multi-slot aggregation is beneficial for VoIP PUSCH coverage enhancements. It is recommended to support sub-PRB transmission with multi-slot aggregation for VoIP for PUSCH in Rel-17.
* Cross-slot channel estimation is beneficial for PUSCH coverage enhancements. It is recommended to support cross-slot channel estimation for PUSCH in Rel-17.
* Lower DM-RS density in time domain with DM-RS sharing among multiple PUSCH transmissions is beneficial for PUSCH coverage enhancements. It is recommended to support lower DM-RS density in time domain with DM-RS sharing among multiple PUSCH transmissions in Rel-17.

1. RAN1 #102-e agreements

**Agreements:**

* **Capture the following updated structure in TR 38.830.**

**6.1 PUSCH coverage enhancements**

**6.1.1 Time-domain based solutions**

**6.1.2 Frequency-domain based solutions**

**6.1.3 DM-RS enhancements**

**6.1.4 Power-domain based solutions**

**6.1.5 Spatial-domain based solutions**

**6.1.6 Others**

**Agreements:**

* Prioritize the study on the performance and specification impacts on time domain based solutions for PUSCH enhancements, including
  + Increase the number of repetitions for PUSCH repetition type A
    - PUSCH repetition with non-consecutive slots/on the basis of available slots for TDD
    - Note: whether increasing the number of PUSCH repetition for FDD depends on the outcome of AI 8.8.1.1.
  + Enhancement on PUSCH repetition Type B
    - E.g., actual repetition across the slot boundary, or the length of actual repetition larger than 14 symbols, etc.
  + TB processing at least over multi-slot PUSCH
    - e.g., single TB, sized for a single slot, but transmitted in parts over multiple slots; or single TB, sized for multiple slots, transmitted over multiple slots, and in conjunction with repetition, etc.
* FFS
  + OCC spreading based repetition
  + Symbol-level repetition
  + TB interleaving
  + RV repetition
  + Early termination of PUSCH repetitions

**Agreements:**

* Following solutions are not considered for PUSCH enhancements in this study item in RAN1:
  + Enhancements to improve spherical coverage / beam correspondence
  + Reflective arrays
  + Polarization aspects of the UL and/or DL reference signals

**Agreements:**

* Prioritize the study on the performance and specification impacts on DM-RS enhancements for PUSCH, including
  + Cross-slot channel estimation
  + With a lower priority compared with cross-slot channel estimation (i.e., companies are encouraged to study it)
    - Lower density
      * E.g., DM-RS sharing among multiple PUSCH transmissions or lower DMRS density in the frequency domain.
    - Higher density
      * E.g., in time or frequency domain, e.g., 1-comb pattern
    - Adaptive configuration
    - DM-RS balancing among frequency hops

**Agreements:**

* Multiple layer PUSCH transmission with DFT-S-OFDM for PUSCH enhancements can be studied with low priority.
* Study open-loop/closed loop Tx diversity for PUSCH enhancements with low priority.

**Agreements:**

* Study the performance and specification impacts on frequency domain based solutions for PUSCH, including
  + Inter-slot frequency hopping
    - with more frequency offsets
    - with more frequency hopping positions.
  + Inter-slot frequency hopping with inter-slot bundling to enable cross-slot channel estimation
  + Enhancements on frequency hopping for PUSCH repetition type B
    - Note that the above inter-slot frequency hopping enhancement can apply for PUSCH repetition type B
  + Sub-PRB transmission for VoIP
    - FFS: details, e.g., number of tones, multi-slot aggregation
* FFS
  + Intra-slot frequency hopping
    - with more frequency offsets
    - with more frequency hopping positions.

[Note: Appropriate simulation assumptions are expected.]

**Agreements:**

* Study following power domain based solution for PUSCH enhancements
  + Waveform design to optimize MPR/A-MPR
  + [FDD high power UE]
  + Power boosting for pi/2 BPSK

Note: if a LS to RAN4 (for the last two bullets) is deemed necessary, target sending the LS in the 1st week of RAN1#103-e.

1. Reference
2. 3GPP RP-200861, “Revised SID on Study on NR coverage enhancements”, China Telecom, RAN#88e, June 29th – July 3rd, 2020.
3. “3GPP TSG RAN WG1 RAN1 #102e Chairman’s Notes”, e-Meeting, Aug. 17th – 28th, 2020.
4. R1-2007583 Potential solutions for PUSCH coverage enhancement Huawei, HiSilicon
5. R1-2007640 PUSCH coverage enhancement Beijing Xiaomi Mobile Software
6. R1-2007680 Discussion on Solutions for PUSCH coverage enhancement vivo
7. R1-2007743 Discussion on potential techniques for PUSCH coverage enhancements ZTE
8. R1-2007874 Discussion on potential techniques for PUSCH coverage enhancement CATT
9. R1-2007905 PUSCH coverage enhancements Indian Institute of Tech (H)
10. R1-2007930 Potential techniques for NR coverage enhancements Sierra Wireless, S.A.
11. R1-2007954 On potential techniques for PUSCH coverage enhancement Intel Corporation
12. R1-2007989 PUSCH coverage enhancement ETRI
13. R1-2007994 Discussion on PUSCH coverage enhancements China Telecom
14. R1-2008026 Discussion on the PUSCH coverage enhancement CMCC
15. R1-2008078 Discussion on PUSCH coverage enhancement NEC
16. R1-2008092 Potential solutions for PUSCH coverage enhancement Spreadtrum Communications
17. R1-2008181 PUSCH coverage enhancement Samsung
18. R1-2008271 Consideration on PUSCH coverage enhancement OPPO
19. R1-2008370 On PUSCH coverage enhancement techniques Sony
20. R1-2008378 Discussion on PUSCH coverage enhancements Panasonic Corporation
21. R1-2008399 PUSCH coverage enhancement Sharp
22. R1-2008403 Discussions on PUSCH coverage enhancement LG Electronics
23. R1-2008419 PUSCH coverage enhancement Ericsson
24. R1-2008479 On potential techniques for PUSCH coverage enhancement Apple
25. R1-2008483 PUSCH coverage enhancements InterDigital, Inc.
26. R1-2008559 Potential techniques for PUSCH coverage enhancements NTT DOCOMO, INC.
27. R1-2008626 Potential coverage enhancement techniques for PUSCH Qualcomm Incorporated
28. R1-2008700 On the use of Tx diversity in DFT-s-OFDM for PUSCH coverage enhancement NICT
29. R1-2008703 Discussion on approaches and solutions for NR PUSCH coverage enhancement Nokia, Nokia Shanghai Bell
30. R1-2008729 Discussion on potential techniques for PUSCH coverage enhancement WILUS Inc.
31. R1-2008743 On transmit diversity techniques for PUSCH coverage enhancement Mitsubishi Electric RCE
32. R1-2007483 [102-e-Post-NR-CovEnh-02] Phase 3: initial collection of simulation results for enhancements Moderator (China Telecom)
33. Appendix

### [3] R1-2007583 Huawei, HiSilicon

|  |
| --- |
| ***Observation 1: By joint channel estimation across consecutive PUSCH transmissions, a large coverage gain can be achieved as compared to conventional single slot channel estimation, i.e., 1.4 dB and 2.1 dB SNR gains are obtained at 10% BLER for 2 and 3 slots joint channel estimation, respectively.***  ***Observation 2: By finer scheduling granularity of (re)transmission, a better coverage performance could be obtained while the large DMRS overhead in each finer granularity (re)transmission would degrade the coverage performance.***  ***Observation 3: PUSCH transmissions with finer scheduling granularity and DMRS sharing among multiple PUSCH (re)transmissions can achieve an obvious SNR gain compared to the baseline (a scheduling granularity of 12OS) at 1Mbps target data rate, such as 1.4dB gain can be obtained by the finer scheduling granularity of 2OS.***  ***Observation 4: Enhancement of repetition cancellation in TDD (7:3 DL: UL) with doubled actual repetitions can obtain approximately >2dB SNR gain for both urban and rural scenarios.***  ***Observation 5: A large SNR gain is obtained by FDD higher power transmission as compared to original repetitions, e.g. 1 dB SNR gain at 10% BLER.***  ***Observation 6: By increasing the frequency hopping positions from 2 positions to 4 positions, a >1dB SNR gain can be obtained at 10% BLER for both 4 repetitions with frequency hopping and 8 repetitions with frequency hopping.***  ***Proposal 1: Joint channel estimation across consecutive PUSCH transmissions is recommended for PUSCH coverage enhancement.***  ***Proposal 2: Potential spec impacts to enable joint channel estimation are identical transmission power, precoding and DMRS port, etc., among consecutive PUSCH transmissions.***  ***Proposal 3: Shared DMRS among multiple consecutive PUSCH transmissions with finer scheduling granularity is recommended for PUSCH coverage enhancement, such as non-DMRS configured PUSCH should be supported to reduce DMRS overhead.***  ***Proposal 4: Enhancement of repetition cancellation in TDD to ensure more actual repetitions is recommended for PUSCH coverage enhancement.***  ***Proposal 5: FDD higher power UE transmission is recommended for PUSCH coverage enhancement.***  ***Proposal 6: More frequency hopping positions among multiple repetitions is recommended for PUSCH coverage enhancement.*** |

### [4] R1-2007640 Xiaomi

|  |
| --- |
| ***Proposal 1: For PUSCH type B, it is better to extension actual/nominal repetition to support non-consecutive slots and partial special slot for improving the PUSCH utilization efficiency and enhancing coverage.***  ***Proposal 2: Whether fixed RV repetition solution having an overall performance gain need to be further evaluated. Dynamic RV repetition or finer granularity RV repetition may be better.***  ***Proposal 3: OCC spreading based repetition can increase the spectrum efficiency, it should be considered into the candidate solutions for coverage enhancement.***  ***Proposal 4: The number of inter-slot frequency hops positions can be increased to at least 4 to further improve PUSCH coverage.***  ***Proposal 5: From the perspective of balancing complexity and performance gain, intra-slot frequency hopping should not to be supported.***  ***Proposal 6: Maybe dynamic indication window size and inter-slot bundling size for cross-slot channel estimation is more suitable***  ***Proposal 7: Support inter-repetition bundling to enable DMRS sharing.***  ***Proposal 8: At least actual repetitions segmented from the same nominal repetition in the same or continuous slots can share the same DMRS.***  ***Proposal 9: Support DMRS bundling in Repetition Type B which includes DMRS placement in a special slot.*** |

### [5] R1-2007680 vivo

|  |
| --- |
| ***Observation 1:* *Increase the number of actual repetitions for PUSCH repetition type A have potential specification impacts in the following aspects:***   * ***The maximum number of repetitions for repetition type A should be extended.*** * ***The postponement rules for repetition type A should be supported.***   ***Observation 2: Compared to RV cycling, enhanced RV solution can provide about 2 dB performance gain in some cases.***  ***Observation 3: Enhanced RV solution has potential specification impacts in the following aspects***   * ***Enhanced or new rules of determining RV for each repetition.*** * ***Enhanced or new segment rules of actual repetitions.***   ***Observation 4: For multi-slot PUSCH, applying the same TDRA over multiple slots would result in the discontinuous resource and inflexible allocation, the available resources cannot be fully utilized.***  ***Observation 5: Multi-slot PUSCH scheme has potential specification impacts in the following aspects***   * ***Uniform TDRA or start symbol and length is redesigned for multi-slot PUSCH.*** * ***The computation of TBS and DMRS pattern for multi-slot PUSCH is modified.***   ***Observation 6: Sub-PRB transmission does not have meaningful performance gain over PUSCH repetition type A with the same TBS.***  ***Observation 7: Sub-PRB transmission will lead to significant specification work, if supported.***  ***Observation 8: Phase continuity and power consistency among slots or transmissions is not required in current specification.***  ***Observation 9: Joint channel estimation have potential specification impacts in the following aspects***   * ***UE need to keep the same Tx power across PUSCH transmission if coherent transmission is configured;*** * ***Potential UE behavior if the coherency of PUSCH repetitions is impacted by other procedures, e.g. simultaneous transmission if configured with CA;*** * ***The granularity in time domain should be defined for joint channel estimation.***   ***Proposal 1: For PUSCH repetition type A, it is beneficial to postpone the PUSCH repetition if the resources are not available.***  ***Proposal 2: Enhanced RV solutions for PUSCH repetition type B transmission should be considered.***  ***Proposal 3: It is beneficial to support multi-slot PUSCH for coverage enhancement.***  ***Proposal 4: More frequency hops for inter slot frequency hopping should be considered with higher priority.***  ***Proposal 5: Intra-repetition frequency hopping for PUSCH repetition type B should be deprioritized.***  ***Proposal 6: sub-PRB transmission is not supported for PUSCH coverage enhancement.***  ***Proposal 7: It is beneficial for joint channel estimation to guarantee phase continuity and power consistency among multiple slots or transmission.*** |

### [6] R1-2007743 ZTE

|  |
| --- |
| ***Observation 1: For VoIP service, 4 repetitions with maximum 1 re-transmission can provide about 1~1.5 dB gain over 2 repetitions with maximum 3 re-transmissions.***  ***Observation 2: In scenario with TDD frame structure ‘DDDSU’ (S: 10D:2G:2U),***   * ***PUSCH repetition type B with actual repetition cross slot boundary can provide 0.8dB gain, and*** * ***the length of actual repetition with 16 symbols can provide 0.8dB gain.***   ***Observation 3: Increasing the number of frequency hopping positions from 2 to 4 could provide additional performance gain for PUSCH repetition.***  ***Observation 4: Frequency hopping together with cross-slot channel estimation can provide performance improvement for PUSCH repetition.***  ***Observation 5: Cross-slot channel estimation among 8 PUSCH repetitions can provide 1.8 dB gain in urban scenario.***  ***Observation 6: Lower DMRS density with only mapping DMRS on half of the PRBs could provide about 1 dB performance gain.***  ***Proposal 1: For PUSCH repetition type A, the number of repetitions indicated by gNB should be guaranteed in case of collisions.***  ***Proposal 2: For PUSCH repetition type B, support actual PUSCH transmission across the slot boundaries and the length of actual repetition larger than 14 symbols.***  ***Proposal 3: Early termination can be considered for NR coverage enhancement.***  ***Proposal 4: OCC spreading based PUSCH can be considered for NR coverage enhancement.***  ***Proposal 5: Enhancement to inter-slot frequency hopping is supported for NR coverage enhancement.***   * ***More frequency hopping positions can be considered.***   ***Proposal 6: For PUSCH repetition, support enhanced frequency hopping schemes to enable cross-slot channel estimation among repetitions per hop.***  ***Proposal 7: Cross-slot channel estimation among PUSCH repetitions should be supported.***   * ***Further study whether phase continuity can be kept across slot boundary.***   ***Proposal 8: Support lower DMRS density in the frequency domain for NR coverage enhancement.*** |

### [7] R1-2007874 CATT

|  |
| --- |
| ***Observation 1: The benefit of TB processing over multiple slots needs more justification.***  ***Observation 2: The motivation of introducing sub-PRB resource allocation needs more justification.***  ***Observation 3: The motivation of introducing multi-layer DFT-s-OFDM is not clear.***  ***Observation 4: Cross-slot channel estimation is up to gNB implementation.***  ***Observation 5: The benefit of DMRS density enhancement needs further justification.***  ***Proposal 1: Increasing the repetition number is supported, including:***   * ***Increasing the repetition number;*** * ***Supporting non-consecutive slots repetition on the basis of available slot/symbols.***   ***Proposal 2: Repetition type B enhancement should be studied for PUSCH.***  ***Proposal 3: Power domain based enhancement should be carefully studied by RAN4 before starting any specification work in RAN1.*** |

### [8] R1-2007905 Indian Institute of Tech (H)

|  |
| --- |
| ***Observation 1: 5G NR coverage enhancement should support additional [x] dB increase in MCL over rel-16 of 5G NR.***  ***Observation 2: Coverage enhancement SI should support higher MCL which directly results in higher ISD compared to existing IMT-2020 evaluations.***  ***Observation 3: UE with 26 dbm max Tx power for UL duty cycle < 50% provides a substantial increase in cell edge data rates.***  ***Proposal 1: Identify [x] dB via system and link-level simulations.***  ***Proposal 2: Study enhanced TBS calculations to increase the MCL for Rel-17 by supporting transmissions over multiple UL slots.***  ***Proposal 3: Make pi/2 BPSK power boosting a function of the UL duty cycle.***  ***Proposal 4: Send LS to RAN4 to study the feasibility of power boosting for pi/2 BPSK modulation beyond 26 dBm as a function of the UL duty cycle.*** |

### [9] R1-2007930 Sierra Wireless

|  |
| --- |
| ***Observation 1: Adding gaps between repeats to improve time diversity is a prioritized time-domain based solution***  ***Observation 2: Filling the gaps with TBs from the same user, maintains the data rate even when gaps are used.***  ***Observation 3: Allowing the gaps to be filled with TBs from other users, improves scheduling flexibility.***  ***Observation 4: With FH disabled, 2.5 dB of gain can be achieved when adding gaps between repeats.***  ***Observation 5: With FH enabled, 2.0 dB of gain can be achieved when adding gaps between repeats.***  ***Observation 6: The multi-slot encoding technique provides similar SNR gains to adding gaps between repeats.***  ***Observation 7: Advantages of gaps between repeats over multi-slot encoding:***   * ***Improved support for small TBS (e.g. VoIP TBS = 320bits)*** * ***Supports larger time diversity (e.g. beyond 64ms)*** * ***Scheduling flexibility (i.e. allows other users to be scheduled in gaps)***   ***Proposal 1: For the eMBB use cases, do not recommend specifying increased repetition for the PUSCH or PDSCH***  ***Proposal 2: Recommend that gaps between repeats be specified as a Rel 17 Coverage enhancement solution***  ***Proposal 3: e (LTE-M) scheme be specified to improve coverage for VoIP.*** |

### [10] R1-2007954 Intel

|  |
| --- |
| **Observation 1**   * *~2dB performance gain can be observed when doubling the repetition levels for PUSCH.*   **Observation 2**   * *Compared to single slot transmission with same code rate, TB spanning multiple slots can deliver similar link level performance.* * *For TB spanning 4 slots with 1 PRB in each slot, ~6dB performance gain can be achieved in term of link budget over single slot transmission with 4 PRBs.*   **Observation 3**   * *For Rel-15 inter-slot frequency hopping pattern, cross-slot channel estimation can provide ~2dB performance gain compared to the case without cross-slot channel estimation.* * *When employing cross-slot channel estimation, Rel-15 intra-slot and inter-slot frequency hopping patterns have similar performance.* * *When employing cross-slot channel estimation, ~1.0dB performance gain can be achieved by enhanced inter-slot frequency hopping pattern, compared to Rel-15 intra-slot and inter-slot frequency hopping pattern.* * *Compared to Rel-15 inter-slot frequency hopping without cross-slot channel estimation, substantial performance gain, i.e., ~3dB can be achieved by enhanced inter-slot frequency hopping with cross-slot channel estimation.*   **Observation 4**   * *When 2 Rx antennas are used, ~1.5dB performance gain can be achieved for 4 frequency hops compared to 2 frequency hops.* * *When 4 Rx antennas are used, ~0.3dB performance gain can be achieved for 4 frequency hops compared to 2 frequency hops.*   **Observation 5**   * *For 8 repetitions with inter-slot frequency hopping, 4 DMRS symbols can achieve better link level performance than 5 and 6 DMRS symbols for PUSCH.*   **Observation 6**   * *For 8 repetitions with intra-slot frequency hopping, performance difference is small for the cases when DMRS symbols are not allocated in odd slots and when DMRS symbols are allocated in each slot.*   **Proposal 1**   * *Maximum number of repetitions can be increased for PUSCH coverage enhancement, especially for TDD configuration with limited UL slots.* * *It is desirable to allow UE to postpone PUSCH transmission in TDD system, until all the configured/indicated number of repetitions is reached.*   **Proposal 2**   * *Enhancement on PUSCH repetition type B in time domain needs to be carefully studied in WI phase with considerations of impacts on UE implementation.*   **Proposal 3**   * *A TB with TBS determined for multiple slots and transmitted over multiple slots can be considered for PUSCH coverage enhancement.*   **Proposal 4**   * *Inter-slot frequency hopping with inter-slot bundling is supported in conjunction with cross-slot channel estimation for PUSCH coverage enhancement.*   **Proposal 5**   * *Increasing the number of frequency hops from 2 to 4 for inter-slot frequency hopping may not be supported for NR coverage enhancement WI, when considering practical gNB receiver architecture.*   **Proposal 6**   * *Depending on coverage enhancement target for VoIP, sub-PRB based resource allocation may not be considered for PUSCH coverage enhancement.*   **Proposal 7**   * *Higher DMRS density in time domain is not supported for PUSCH coverage enhancement.*   **Proposal 8**   * *Lower DMRS density in time domain is not supported for PUSCH coverage enhancement.* |

### [11] R1-2007989 ETRI

|  |
| --- |
| ***Proposal 1: For repetition type A enhancement, study the way to guarantee the number of repetition as being indicated.***  ***Proposal 2: For repetition type A enhancement, study to indicate more than one SLIVs in a single UL grant.***  ***Proposal 3: For repetition type B enhancement, relax the definition of a time window, i.e., include only valid symbols.***  ***Proposal 4: For joint channel estimation, study the enhanced power control to keep similar or even same power level during all repetitions.*** |

### [12] R1-2007994 China Telecom

|  |
| --- |
| ***Observation 1: The enhanced repetition mechanism, the number of repetitions counted on the basis of available UL slots, can improve the performance of voice service for both O2I and O2O scenario. About 3.2dB and 4dB gain at target 2% rBLER can be obtained for O2I and O2O respectively.***  ***Observation 2: Compared with Rel-16 repetition type B, the enhanced repetition type B can improve the performance of voice service for both O2I and O2O scenarios. About 0.8 dB gain at target 2% rBLER can be obtained for both O2I and O2O scenarios.***  ***Observation 3: Compared with Rel-16 repetition type A, TB processing over multi-slot PUSCH can improve the performance of voice service for both O2I and O2O scenarios. About 1.0 dB gain and 0.6dB gain at target 2% rBLER can be obtained for O2I and O2O scenarios respectively.***  ***Observation 4: TB processing over multi-slot PUSCH can improve the performance of eMBB for rural scenario. About 1.3 dB gain and 2.7dB gain at target 10% iBLER can be obtained for TB processing over 2 slots and 4 slots respectively.***  ***Observation 5: The enhanced frequency hopping scheme can improve the coverage performance. About 0.4dB gain at target 10% iBLER and 1.8dB gain at target 2% rBLER can be obtained for eMBB and VoIP respectively compared with Rel-16 frequency hopping scheme.***  ***Observation 6: Inter-bundle frequency hopping can improve the coverage performance. Compared with Rel-16 inter-slot frequency hopping, about 0.5dB gain at target 2% rBLER for VoIP service can be obtained for inter-bundle frequency hopping.***  ***Observation 7: Sub-PRB transmission can improve the coverage performance. Compared with Rel-16 repetition type A, about 0.8dB gain can be obtained at target 2% rBLER for sub-PRB transmission for voice service.***  ***Observation 8: Cross-slot channel estimation can improve the coverage performance. About 0.4dB and 0.8 dB gain at target 10% iBLER can be observed for TDD (DDDSUDDSUU) and FDD respectively.***  ***Observation 9: 1-comb DM-RS can improve the coverage performance. About 0.5dB and 1.5 dB gain at target 10% iBLER can be obtained for eMBB for urban and rural scenarios respectively.*** |

### [13] R1-2008026 CMCC

|  |
| --- |
| ***Observation 1: 0.4 dB gain could be achieved through the cross-slot channel estimation over 2 slots for PUSCH eMBB traffic.***  ***Observation 2: In addition to the cross-slot channel estimation, a lower DMRS density and fully utilized sources in special slot could improve the coverage of PUSCH. And about 1.22 dB coverage gain could be achieved.***  ***Proposal 1: Different symbol allocations applied in different slots for PUSCH repetition Type A can be supported.***  ***Proposal 2: PUSCH repetition on non-consecutive physical available resources for PUSCH transmission can be supported, both PUSCH repetition Type A and Type B can be considered.***  ***Proposal 3: Early termination for PUSCH repetitions can be supported to reduce unnecessary network UL resource occupation and reduce unnecessary UE power consumption.***  ***Proposal 4: Fully use of resources in the special slot should be considered for the PUSCH coverage enhancement.***  ***Proposal 5: A reduced DM-RS density could spare more resources for PUSCH to improve the coverage.***  ***Proposal 6: An adaptive configuration of DMRS could improve the operation flexibility according to different scenarios.***  ***Proposal 7: The lower density and adaptive configuration of DMRS should be prioritized.*** |

### [14] R1-2008078 NEC

|  |
| --- |
| ***Proposal 1: It’s beneficial to support cross channel. Based on legacy NR, channel across different slot are not inferable. Inferable state could be indicated to UE to support cross channel estimation.***  ***Proposal 2: To study different number of DMRS symbol in each slot to make up DMRS symbol pattern over multiple slots when cross slot channel estimation adopted.***  ***Proposal 3: It's beneficial to study providing more frequency hopping RB position to increase the coverage. Inter-slot frequency hopping with inter-slot bundling to enable cross-slot channel estimation should be supported.*** |

### [15] R1-2008092 Spreadtrum

|  |
| --- |
| ***Proposal 1. The repetition number of dynamic scheduled PUSCH/configured grant PUSCH should be increased, e.g., 32, 64, etc.***  ***Proposal 2. Don’t support increasing maximum number of symbols for PUSCH***  ***Proposal 3. For both inter/intra-slot hopping, the supported PUSCH hoping positions/number should be increased, e.g., 4, 8, etc.***  ***Proposal 4. Postpone the discussion on enhancements on frequency hopping for PUSCH repetition type B.***  ***Proposal 5. Sub-PRB transmission is not considered in PUSCH coverage enhancement.***  ***Proposal 6. Support to introduce DMRS-less transmission for PUSCH coverage enhancement in Rel-17.*** |

### [16] R1-2008181 Samsung

|  |
| --- |
| ***Observation 1: Rel-16 PUSCH repetition type B may have loss of coding gain.***  ***Proposal 1: Support an actual repetition across the slot boundary or invalid symbols.***  ***Proposal 2: Support a length of a repetition larger than 14 symbols.***  ***Observation 2: Rel-16 Type A and Type B PUSCH repetition cannot provide flexible utilization of UL symbols which may reduce coverage and resource utilization efficiency.***  ***Proposal 3: A UE considers the slot format indicated by dynamic SFI for adjusting repetitions of a PUSCH transmission to include only UL symbols.***  ***Observation 3: Dropping the transmission of repetitions has negative impact on PUSCH, especially for configured grant. There are trade-offs with both dropping and postponing cancelled repetitions and it is beneficial to enable a gNB to configure either dropping or postponing repetitions to a UE.***  ***Proposal 4: For Type A PUSCH repetition, support postponing/dropping cancelled repetitions for a PUSCH transmission.***  ***Proposal 5: Support enhancements on cross-slot channel estimation.***  ***Proposal 6: Support enhancements on frequency hopping with cross-slot channel estimation.***  ***Proposal 7: Support sub-PRB transmission for coverage enhancement.***  ***Observation 4: The necessary spec impact for sub-PRB transmission is frequency domain resource allocation as well as some consideration in pow*** |

### [17] R1-2008271 OPPO

|  |
| --- |
| ***Observation 1: Assuming the low fixed MCS, the BLER performance can be improve while the target throughput for eMBB in Urban Scenarios cannot be improved with repetition enhancement only. The while the target throughput for eMBB in Rural Scenarios can be enhanced by repetition.***  ***Observation 2: Repetition scheme can also enhance the coverage in lower SNR and data rate lower than the target eMBB data rate.***  ***Observation 3: When the maximum number of effective transmissions is fixed, adaptive repetition can achieve better performance. The adaptive repetition can be supported by HARQ mechanism with high control overhead or by enhance repetition mechanism.***  ***Observation 4: PUSCH/PDSCH slot aggregation would restrict flexible slots as uplink/downlink, which restricts the scheduling flexibility.***  ***Proposal 1: Slot aggregation and dynamic repetition can be considered as the baseline for Rel-17 PUSCH coverage enhancement.***  ***Proposal 2: Introducing higher aggregation factor for PUSCH repetition and adaptive PUSCH repetition with earlier termination.***  ***Proposal 3: Restricting PUSCH repetition in preconfigured valid slots.***  ***Proposal 4: Cross-slot estimation, DMRS-less and non-uniform distributed DMRS can be considered for PUSCH repetition.***  ***Supporting frequency hopping of PUSCH based on multiple slots.***  ***Proposal 5: During PUSCH repetition, different PUSCH spatial filter parameters and different antenna ports can be applied for different PUSCH slots.***  ***Proposal 6: High power UE for FDD shall be discussed in RAN4.*** |

### [18] R1-2008370 Sony

|  |
| --- |
| ***Proposal 1: Coverage enhancement supports the coverage enhancement of CG-UCI and CG-PUSCH****.*  ***Observation 1: Pairwise repetition of CG-UCI and CG-PUSCH reduces PUSCH buffering and allows for earlier PUSCH decoding****.*  ***Proposal 2: CG-UCI and CG-PUSCH are repeated in pairwise fashion****.*  ***Observation 2: If the DM-RS density can be dynamically changed in both time and frequency domains, the throughput of the PUSCH can be optimized both with respect to time and frequency selective channel conditions.***  ***Proposal 3: Adaptive configuration of DM-RS to improve PUSCH coverage should be studied.***  ***Proposal 4: For PUSCH, frequency hopping with at least four hops is supported through multiple configured grants****.*  ***Proposal 5: For PUSCH frequency hopping, the gNB can dynamically adapt the frequency hopping pattern, based on which hops are more effective****.*  ***Observation 3: A higher transmit power UE can improve PUSCH coverage****.*  ***Observation 4: An HD-FDD UE can transmit a higher power than an FD-FDD UE while using the same PA****.*  ***Proposal 6: Coverage enhancement supports half-duplex FDD UEs****.*  ***Proposal 7: Coverage enhancement supports sub-PRB PUSCH transmission****.*  ***Proposal 8: Send an LS to RAN4 recommending that RAN4 study higher transmit power FDD UEs and negative MPR / power boosting****.* |

### [19] R1-2008378 Panasonic

|  |
| --- |
| ***Observation 1: The repetition enhancement such that the number of repetitions is counted on the basis of available UL slots is useful if the resource usage of PDCCH needs to be reduced like PDCCH repetition.***  ***Proposal 1: In order to support cross-slot channel estimation, RAN1 asks to RAN4 in what condition phase continuity can be kept.***  ***Observation 2: For the repetition with DMRS enhancement, DMRS distribution over the duration of repetition is important for the trackability to channel variation.***  ***Observation 3: DMRS allocation of PUSCH repetition Type A with cross-slot 2D MMSE channel estimation can provide better averaging and interpolation performance.***  ***Observation 4: Single TB, sized for multiple slots, transmitted over multiple slots could be considered up to 1/3 or 1/5 coding rate. Further lower coding rate is realized by the repetition.***  ***Observation 5: In the combination with cross-slot/cross-repetition channel estimation, frequency hopping enhancement such as configurable time domain hopping interval should be supported.*** |

### [20] R1-2008399 Sharp

|  |
| --- |
| ***Proposal 1: Capture DMRS bundling as a candidate solution for coverage enhancement in the TR.***  ***Proposal 2: DMRS-less repetition in the aggregated slot can be considered.***  ***Proposal 3: TBS scaling is required to meet the target data rate requirement in a PUSCH transmission with aggregated slot.***  ***Proposal 4: DMRS allocation can be based on the aggregated resource or the nominal repetition instead of the actual repetition.***  ***Proposal 5: For repetition type B, TBS scaling can be considered with***  ***Option 1: Scaling based on the amount of time resources or***  ***Option 2: Longer nominal repetition length than 14.***  ***Proposal 6: Increased number of repetitions can be considered for VoIP coverage enhancement.*** |

### [21] R1-2008403 LG

|  |
| --- |
| ***Proposal 1: To increase the number of PUSCH repetitions in unpaired spectrum, PUCCH repetition principle can be reused for PUSCH***  ***Proposal 2: Flexible symbol resource allocation depending on PUSCH repetition slot should be studied for PUSCH coverage enhancement.***  ***Observation 1: PUSCH TB mapping over multi-slot is beneficial in terms of performance gain and frequency-domain multiplexing.***  ***Proposal 3: Symbol-level combining should be studied to enhance PUSCH coverage. Symbol-level combining can be supported by applying the same RV value during a bundle of PUSCH slots.***  ***Proposal 4: To support cross-slot channel estimation, the same beam direction, precoding matrix, and PRB location should be applied for PUSCH repetitions during the slots.***  ***Proposal 5: Enhancement of DMRS density does not seems to be necessary.***  ***Proposal 6: To support bundled slot wise frequency hopping, the location and number of bundled slot need to be discussed further.***  ***Proposal 7: For sub-PRB transmission, related topics (i.e., TB mapping, DMRS mapping) should be studied.*** |

### [22] R1-2008419 Ericsson

|  |
| --- |
| ***Observations:***   * *Non-coherent and partially coherent UE’s PAPR or cubic metric (CM) of multiple layer PUSCH transmission is not higher than 1-layer PUSCH transmission by coherent UE.* * *Multiple layer PUSCH transmission with DFT-S-OFDM can improve PUSCH cell coverage.* * *Multiple layer transmission is especially beneficial in the non-coherent UEs that are those most used in real deployment, since multi-layer transmission provides more power in these UEs.*   + *Pure rank 1 transmission tends to be infrequent even for UEs in the poorest channel conditions when few gNB antennas are used.*   + *When massive MIMO gNBs are used, rank 1 is almost never selected.* * *Cross-slot channel estimation brings gains, but further study is needed on how much needs to be specified vs. what can be done in gNB implementation (e.g. by estimating wideband phase corrections to combine slots).* * *Using 4 instead of 2 hops can bring modest gains in a limited set of scenarios.* * *SigComp can compress SIP packets at application layer before encryption is used. This feature should be considered for Voice coverage enhancement. It has better potential i.e. suitable for all scenarios regardless of whether packets are encrypted or unencrypted.* * *Early CSI may also benefit the Voice Service. Having accurate CSI for a UE in poor coverage that wants to send a large UL SIP packet such as INVITE can allow the network to apply schemes such as beamforming, frequency selective scheduling, robust modulation and coding schemes, etc.*   *Based on the observations and discussions, we have following proposals.*  ***Proposals:***   * *Consider at least the following areas for UL coverage enhancement:*   + *Improvements to low PAPR transmission*   + *Multi-antenna techniques*   + *Cross-slot channel estimation* * *Specify multiple layer PUSCH transmission with DFT-S-OFDM.* * *Indicate to CT1 and SA4 that 2KB SIP message sizes may impact VoNR coverage or setup latency in arduous coverage scenarios and ask if SigComP functionality can be supported to reduce SIP message overhead.* * *Ask CT1/SA4 what SIP message packet sizes and arrival rates can be expected.* |

### [23] R1-2008479 Apple

|  |
| --- |
| ***Proposal 1:The coverage enhancement solutions should be down selected further according to the performance and standard impacts***  ***Proposal 2: The benefits of TB processing over multi-slot, sub-PRB transmission and frequency hopping enhancement for PUSCH repetition type B need to be studied further.***  ***Observation:***   * ***At low SNR operating point, PUSCH performance is improved with one more DM-RS symbol.*** * ***Intra-slot Frequency hopping can provide benefit with smaller number of PRB allocation and a relative high SNR region.*** * ***Usage several techniques together could provide better performance than single technique applied.*** |

### [24] R1-2008483 InterDigital

|  |
| --- |
| ***Observation 1: The number of DMRS symbols placed in an uplink slot should be minimized without sacrificing channel estimation performance***  ***Observation 2: DMRS symbol can be placed in a special slot which is placed before the uplink slot, allowing channel estimation across the slot boundary***  ***Observation 3: Relying solely on repetitions to meet PUSCH coverage can have the following shortcomings:***  ***1) A non-narrow band frequency allocation, thus reducing the TB’s power spectral density***  ***2) An increase of latency required to transmit the TB/reach the required HARQ operating point***  ***3) Increased cell load, which may come at the cost of other service types or users in the cell.***  **This contribution proposes to support the following enhancements**  ***Proposal 1:Support DMRS placement in a special slot which can be bundled with DMRS in the adjacent uplink slot***  ***Proposal 2:Support frequency hopping pattern which contains bundled DMRS in the same hop.***  ***Proposal 3: Support DMRS bundling for repetition type A and B***  ***Proposal 4: Support the use of uplink symbols in the adjacent special slot to extend duration of PUSCH***  ***Proposal 5: Support repetition of PUSCH over non-consecutive slots***  ***Proposal 6: Support TB scheduling over consecutive slots in the time domain without repetition***  ***Proposal 7 Support TB encoding for transmission of coded TB segments mapped over multiple slots***  ***Proposal 8: Support partial TB retransmission for TBs transmitted over a multi-slot PUSCH***  ***Proposal 9: Support methods to minimize MPR of the waveform*** |

### [25] R1-2008559 NTT DOCOMO

|  |
| --- |
| ***Proposal 1: Extension of PUSCH repetition to support non-consecutive slots can be one of the potential techniques for PUSCH coverage enhancement.***  ***Proposal 2: More efficient utilization of partial slot with next full slot for PUSCH can be one of the potential techniques for PUSCH coverage enhancement.***  ***Proposal 3: High PSD (small number of PRBs) with high coding rate may have advantage for coverage performance, and additional PRB unit with smaller number of subcarriers (e.g. half PRB with 6 subcarriers) can be one of the potential techniques for PUSCH coverage enhancement.***  ***Proposal 4: Frequency hopping with multiple frequency offsets can be one of the potential techniques for PUSCH coverage enhancement.***  ***Proposal 5: Denser DM-RS mapping (e.g., 2 for DM-RS symbol duration, and pos3 for additional DM-RS symbol position) can be expected for enhancement of coverage performance.***  ***Proposal 6: Cross-slot channel estimation with non-consecutive PUSCH slots should be also considered for the performance evaluation.*** |

### [26] R1-2008626 Qualcomm

|  |
| --- |
| ***Proposal 1: For enhancing the coverage of PUSCH, consider techniques for UE transmit waveform design that allow further reduction in the MPR values for DFT-S-OFDM and CP-OFDM waveforms. In particular, consider tone reservation principle for DFT-s-OFDM and CP-OFDM waveforms to further reduce PAPR.***  ***Proposal 2: Consider DMRS bundling technique for coverage enhancement in Rel-17.***  ***Observation: Using appropriate DMRS configuration could provide up to 1.7dB gain per fixed MCS and tens of percent of TPUT increase at cell edge scenarios for PUSCH.***  ***Proposal 3: Introduce a new mechanism for dynamic DMRS configuration signaling to enable DMRS adaptation in Rel-17.***  ***Proposal 4: Consider the following signaling options for dynamic DMRS configuration***   * ***Option 1: Dynamic MAC-CE based activation and complementary DCI based selection of one of the activated DMRS configuration options.*** * ***Option 2: Single active DMRS configuration option that is dynamically activated by MAC-CE to adopt DMRS configuration to channel and SNR conditions.***   ***Proposal 5: Introduce a new mechanism for dynamic signaling of the transmission scheme to enable waveform adaptation to reception conditions associated with PUSCH transmissions of a UE.***  ***Proposal 6: Consider the following options for dynamic implicit signaling of the transmission scheme for PUSCH:***   * ***Option 1: Dynamic MAC-CE based activation of the active MCS table. Different RRC configured MCS tables are associated with different waveforms and the activated MCS table provides an implicit indication of the associated waveform.*** * ***Option 2: To define a new hybrid MCS table that will contain a combination of MCSs from MCS tables for DFT-S-OFDM and CP-OFDM transmission schemes while different MCS index ranges will be associated with different waveforms. MSC index indicated for a PUSCH grant will be used as an implicit signaling for the transmission scheme.***   ***Proposal 7: Consider TBS scaling and optimization across multiple slots for PUSCH coverage enhancement in Rel-17.*** |

### [27] R1-2008700 NICT

|  |
| --- |
| ***Observation 1: DFT-s-OFDM is better waveform from viewpoint of reduction of PAPR than CP-OFDM.***  ***Observation 2: The use of Tx diversity is effective to reduce required SNR in PUSCH with DFT-s-OFDM at BLER of 10%. It could contribute to realizing coverage enhancement.***  ***Proposal 1: DFT-s-OFDM is better waveform from viewpoint of reduction of PAPR than CP-OFDM.***  ***Proposal 2: Tx diversity should be introduced in order to realize the reduction of necessary fading margin for coverage enhancement.***  ***Proposal 3: The use of DFT-s-OFDM with Tx diversity should be one of the approaches for coverage enhancement.*** |

### [28] R1-2008703 Nokia, Nokia Shanghai Bell

|  |
| --- |
| ***Observation 1. The coverage for data channel can be improved by using qam64-LowSE MCS index table (table 3), which enables lower code rate as compared to its 256QAM and 64QAM counterparts.***  ***Observation 2. For a fixed number of PRBs, using the lowest possible MCS index, which still guarantees the target throughput, can extend the cell coverage.***  ***Observation 3. The coverage of PUSCH can be enhanced by identifying the optimal combination of number of allocated PRBs and MCS index for PUSCH to meet the throughput target.***  ***Observation 4. The maximum number of repetitions for PUSCH repetition type A in release 15 is sufficient for FDD deployment.***  ***Observation 5. The PUSCH repetition type B can be used to cope with the cancellation due to DL/UL collision in TDD deployment. Therefore, the consideration of counting repetition numbers based on non-consecutive slots for PUSCH repetition type A may not be needed.***  ***Observation 6. There is a tradeoff between the time domain diversity gain from PUSCH repetition and the low coding rate gain brought by the potential TB processing over multiple slots. The applicability of this solution in TDD deployment is limited.***  ***Observation 7. The potential advantage of introducing early termination of PUSCH repetition and/or more RVs is unclear and, if any at system-level, likely absent at link-level.***  ***Observation 8. In TDD deployments, the coverage of PUSCH can be significantly enhanced by simply considering the frame structure that maximizes PUSCH coverage while ensuring that DL target throughput is met.***  ***Observation 9. Inter-slot frequency hopping with inter-slot bundling to enable cross-slot channel estimation can be further considered following the outcome of the discussion on cross-slot channel estimation solution.***  ***Observation 10. Specific enhancement for PUSCH repetition type B in frequency domain is not needed. However, generic enhancements agreed in frequency domain, if any, can be considered for PUSCH repetition type B.***  ***Observation 11. Intra-slot frequency hopping can help to improve PUSCH coverage. DMRS overhead can be reduced thanks to cross-slot joint channel estimation/channel information sharing.***  ***Observation 12. Introducing sub-PRB transmission may be beneficial for coverage, in case of low data rate applications.***  ***Observation 13. Cross-slot channel estimation and DMRS-less PUSCH transmission require several constraints to be applicable in practice.***  ***Observation 14. Extending the spectral shaping for QPSK is a potential solution to reduce MPR and to improve UL PUSCH coverage.***  ***Observation 15. FDSS without spectrum extension (defined for pi/2 BPSK in Rel-15) is not beneficial for QPSK due to the lack of significant gain in terms of CM and PAR.***  ***Observation 16. FDSS with spectrum extension is a potential candidate for shaping with QPSK because it can reduce both CM and PAR efficiently.***  ***Observation 17. The Output Back-Off at PA of the original QPSK waveform is reduced by 1.0-1.7 dB by applying FDSS with spectral extension.***  ***Observation 18. At the PRB allocations of interest for coverage, the OBO difference between pi/2 BPSK FDSS and QPSK FDSS with spectral extension is 0-0.3 dB.***  ***Observation 19. Link performance of QPSK with extend FDSS is comparable to the original QPSK waveform without FDSS.***  ***Observation 20. Link performance of QPSK with extend FDSS is always better compared to the pi/2 BPSK with FDSS.***  ***Observation 21. Coverage of the original QPSK waveform can be improved up to 2 dB by applying FDSS with spectral extension.***  ***Observation 22. At the PRB allocations of interest for coverage, the QPSK FDSS with spectral extension provides in most cases better, and the rest of the cases at least comparable coverage compared to pi/2 BPSK FDSS.***  ***Proposal 1. In the TR of Rel-17 NR coverage enhancement SI, the following observation should be captured: The coverage for data channel can be improved by using qam64-LowSE MCS index table (table 3), which yields more MCS indices with lower code rate as compared to its 256QAM and 64QAM counterparts, especially in scenarios with low(er) throughput requirements.***  ***Proposal 2. In the TR of Rel-17 NR coverage enhancement SI, the following observation should be captured: The coverage of PUSCH can be enhanced by identifying the optimal combination of number of allocated PRBs and MCS index for PUSCH to meet the throughput target.***  ***Proposal 3. The available features in NR Releases 15 and 16 should be considered when discussing work items for NR coverage enhancement.***  ***Proposal 4. The enhancement on PUSCH repetition type B, e.g. actual repetition across the slot boundary, or the length of actual repetition larger than 14 symbols, is in the same category and should be discussed together with TB processing over multiple slots for PUSCH. The PUSCH coverage enhancement based on PUSCH repetition type B framework should be avoided.***  ***Proposal 5. DMRS balancing should be considered for the design of new DMRS enhancement solutions.***  ***Proposal 6. The FDSS with spectral extension for QPSK is considered as potential solution to reduce MPR and to improve UL PUSCH coverage.*** |

### [29] R1-2008729 WILUS

|  |
| --- |
| ***Proposal 1: Discuss detailed methods about actual repetition across the slot boundary and the length of actual repetition larger than 14 symbols in WI phase.***  ***Proposal 2: Discuss options about RE calculation that extended to multiple slots in WI phase.***  ***-Redesign calculation***  ***-Redesign calculation***  ***Proposal 3: Discuss determination of frequency hopping boundary based on time domain coverage enhancement in WI phase.*** |

### [30] R1-2008743 Mitsubishi Electric

|  |
| --- |
| ***Proposal 1: Alamouti-based transmit diversity is supported for PUSCH with DFTsOFDM.*** |