3GPP TSG RAN Meeting #91e RP-210660
Electronic Meeting, March 16 - 26, 2021
Agenda Item: 9.7.4
Document for: discussion and decision

On DSS WID objective of single DCI for scheduling PDSCH on 2 cells

Huawei, HiSilicon, China Telecom, China Unicom

R17 DSS scope and RAN1 status

- The Rel-17 DSS WID addresses the PDCCH capacity issue as the number of NR devices increases.
- RAN1 studied using single DCI joint scheduling PDSCH on 2 carriers, and led to some observations, which are captured in moderator summary of R1-2102138.
- This contribution provides a comprehensive understanding of RAN1 observations and results, and proposes to confirm the support of the objective in Rel-17 work item.

3 Justification

Dynamic spectrum sharing (DSS) provides a very useful migration path from LTE to NR by allowing LTE and NR to share the same carrier. DSS was included already in Rel-15 and further enhanced in Rel-16. As the number of NR devices in a network increases, it is important that sufficient scheduling capacity for NR UEs on the shared carriers I ensured.

4 Objective

4.1 Objective of SI or Core part WI or Testing part WI

This work item is limited to FR1, and includes the following objectives for NR Dynamic Spectrum Sharing (DSS):

- PDCCH enhancements for cross-carrier scheduling including [RAN1, RAN2]
  - PDCCH of SCell scheduling PDSCH or PUSCH on P(S)Cell
  - Study, and if agreed specify PDCCH of P(S)Cell/SCell scheduling PDSCH on multiple cells using a single DCI
    - The number of cells can be scheduled at once is limited to 2
    - The increase in DCI size should be minimized
- Note: The total PDCCH blind decoding budget should not be changed as a result of this work
- Note: These enhancements are not specific to DSS and are generally applicable to cross-carrier scheduling in carrier aggregation

RAN1#104-e (Jan/Feb 2021)

Agreement

- The proposal in section 2.6 of R1-2102138 for PDCCH blocking probability taken as RAN1 observation
- The proposal in section 2.6 of R1-2102138 for PDSCH throughput is taken as RAN1 observation with the following revision for the note:
  - Note: Combinations 1 and 2 were agreed for evaluation. Some companies provided evaluation results for Combinations 3 and 4.

Agreement

The observations for multi-cell PDSCH scheduling via a single DCI to be summarized in the status report along with explanation on different combinations that were considered for submission to RAN.

Note:

for simplicity, PDCCH for scheduling multi-carrier is denoted as *mDCI*.

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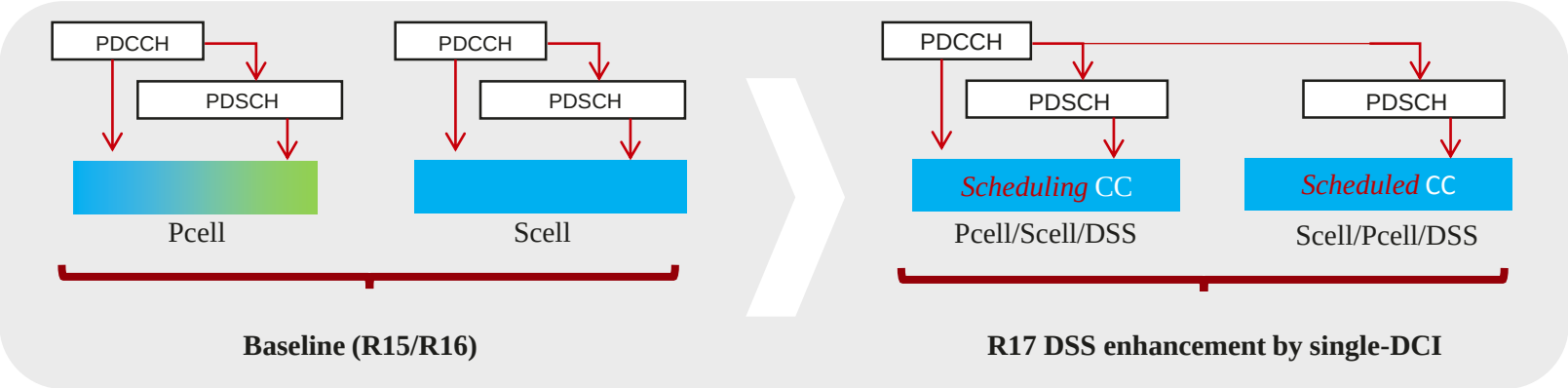
RAN1 evaluation assumptions



Notes:

- **Shared DCI fields for 2 PDSCHs/PUSCHs is feasible**
  - Single DCI for multi-slot PUSCH scheduling already specified in Rel-16, single DCI for multi-slot PDSCH scheduling agreed in Rel-17 for above 52.6 GHz
- **DCI blind detection budget ≠ DCI size budget (DCI size alignment among DCI formats)**
- **Gains can only be seen with DL CA traffic. Without DL traffic or without users configured for CA, it is obvious that network has no interest in configuring single-DCI**

Scenarios ("combinations")

- **For scheduling carrier**
  - Comb-1: 2GHz, 15kHz, 2T2R, 20MHz, 2OS*96RB
  - Comb-2: 4GHz, 30kHz, 4T4R, 100MHz, 1OS*270RB
  - Comb-3: 700MHz, 15kHz, 2T2R, 10MHz, 3OS*48RB
  - Comb-4: 4GHz, 30kHz, 4T4R, 40MHz, 2OS*96RB
- **For scheduled carrier:**
  - 700MHz/2GHz with 10/20MHz BW

Candidate PDCCH payload

- **60 bits as baseline, based on mean values of each field of a DCI format 1_1 (excluding CRC)**
- **72/84/96/108 bits evaluated for mDCI (2*60-X bits, X bits are saved compared to baseline)**
  - 108 bits can be directly achieved based on CA with sharing a single PUCCH in a PUCCH group
  - 96 bits can be easily achieved by further sharing some DCI fields for applicable scenarios
    - e.g. with almost no scheduling flexibility reduction, two FDD carriers can share BWP indicator, VRB-to-PRB mapping, PRB bundling size, TCI, etc

CA vs. non-CA scheduling

- **Number of users**
  - 10/15/20 UEs per cell. 5 users were also considered.
  - CA ratio of 10%, 50%, 80% or 100% among all users.
- **Total DCI blind detection budget needs to be kept**
  - Same as for objective 1 of the WID
  - Fallback DCI only on Pcell (no CSS on scheduling Scell)

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RAN1 observations analysis

Metric and methodology

- **PDCCH blocking rate reduction**
  - Percentage of PDCCH/PDSCH that cannot be scheduled
  - Gain is represented by (b-a)%
    - b% is the PDCCH blocking rate for legacy DCI
    - a% is the blocking rate with mDCI
- **PDSCH throughput improvement**
  - Approach a) by transmitting more PDCCHs in the same CORESET, and multiplexing more users (more PDSCHs) by MU-MIMO (CORESET level rate matching as Rel-15)
  - Approach b) by configuring a smaller CORESET size for mDCI in order to keep the PDCCH blocking rate the same as that for legacy DCI on a larger CORESET

Notes:

- The worst DL throughput results shown by SLS were obtained with the most unfavorable assumptions, including using a small DCI size of 84 bits which leading to strong scheduling restrictions (especially in FDRA) for the irrelevant scenario of 700Mhz carrier scheduling 4Ghz carrier, and no PDCCH blocking reduction implemented.
- Some results were provided as back-of-the-envelope analysis without SLS, showing marginal/no DL throughput gain. Those analysis did not consider MU-MIMO and assumed a limited number of CA UEs.

For two small carriers across FDD bands (Combination 1 and Combination 3)

- **Reducing PDCCH blocking probability**
  - Approximately 3.6%~34% reduction for 5~20 CA users for 96/108 bits DCI
- **Improving PDSCH throughput**
  - (2%~11%) improvement for network average throughput for 5~20 CA users for 96/108 bits DCI without scheduling restriction on RA fields
  - (8%~68%) improvement for cell-edge user throughput

For large CORESET on a scheduling carrier of TDD band (Combinations 2 and 4)

- Similar trend with smaller gains on reducing PDCCH blocking probability
- Up to 2.3% gain or no gain in DL throughput with restriction on RA fields or restricted CA UE numbers

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Summary and proposal

On improving the PDSCH throughput

- Network can choose to configure mDCI only when conditions are appropriate
  - Converting the increased PDCCH capacity into scheduling more users/PDSCHs per slot (approach a) results in higher gains, as shown in Huawei's results, compared to keeping the number of scheduled users/PDSCHs constant.
  - For DSS carriers, the benefits increase as PDCCH capacity is further limited due to LTE CRS overhead, especially when both carriers use DSS.
  - Gain reduces when number of CA users is small in a large CORESET, or when the ratio of UL/DL traffic is 50%: in both cases opportunities for scheduling 2-DL CA users is small, so the DL throughput gain is inherently limited by such assumptions.

On reducing PDCCH blocking probability

- Almost all results show the PDCCH blocking rate can be reduced with mDCI
  - improved PDCCH resource utilization
  - improved PDCCH capacity

Company	Band combination	Gain of payload size of mDCI	
		96 bits	108 bits
Huawei, HiSilicon (R1-21001943)	2GHz+700MHz	7.89%	6.69%
		8.68%	7.13%
		9.07%	7.54%
	2GHz+2GHz	9.43%	7.90%
		10.28%	8.41%
		10.88%	8.93%
	2GHz+700MHz (as DSS carrier with LTE overhead considered)	8.78%	7.38%
		9.60%	7.82%
		10.03%	8.29%

more CA UEs

- **Sufficient PDCCH blocking probability reduction and DL throughput improvement are identified at least for the deployments with 2 carriers over FDD bands, where Objective 1 is not useful as the PDCCH capacity on Scell is also limited.**
- **For scheduling carrier on TDD band (e.g. C-band), using single DCI joint scheduling can also be beneficial.**

- **Proposal➔ RAN to confirm to the following WID revision for R17 DSS WI**
  - ~~Study, and if agreed~~ specify PDCCH of P(S)Cell/SCell scheduling PDSCH on multiple cells using a single DCI

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Appendix

Information	Bits	Common or independent		Evaluation
For transport block 1:		May be preferable to be independent for separate transport blocks		The baseline PDCCH payload is taken as 60 bits excluding CRC, by referring to the mean value of each field in a DCI format 1_1.
Modulation and coding scheme	5			
New data indicator	1			
Redundancy version	2			
For transport block 2:				
Modulation and coding scheme	5			
New data indicator	1			
Redundancy version	2			
HARQ process number	4	Can be fully up to network configuration		The payload of mDCI varies depending on network configurations of these fields, resulting in e.g. 72/84/96 bits.
Bandwidth part indicator	0,1,2			
Rate matching indicator	0,1,2			
ZP CSI-RS trigger	0,1,2			
SRS request	2,3			
Antenna port(s)	4,5,6			
CBG transmission information (CBGTI)	0,2,4,8			
CBG flushing out information (CBGFI)	0 ,1			
Time domain resource assignment	0,1,2,3,4			
VRB-to-PRB mapping	0,1			
PRB bundling size indicator	0,1			
DMRS sequence initialization	1			
Transmission configuration indication	0,3			
Frequency domain resource assignment (104 RB for 20MHz)	13			
TPC command for scheduled PUCCH	2	Common for practical deployments and usage	Same PUCCH within a PUCCH group	The payload of mDCI should be able to reach as small as 108 bits in most scenarios by sharing these fields across two carriers.
Downlink assignment index	0,2,4		Same PUCCH within a PUCCH group	
PDSCH-to-HARQ_feedback timing indicator	0,1,2,3		Similar latency requirement for two PDSCHs	
PUCCH resource indicator	3		Same PUCCH resource for HARQ is enough	
Carrier indicator	3		Common understanding for 2 PDSCH	
Identifier for DCI formats	1		Same DCI format	
CRC	24		One CRC is enough	

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Thank you.