3GPP TSG-RAN WG1#83 **R1-157210**
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Class A PUCCH feedback

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Agenda Item: 6.2.4.3.2

Document for: Discussion and Decision

Background

- Principles of aperiodic/periodic CSI feedback:
  - *Detailed CSI feedback on aperiodic CSI on PUSCH*
  - *Coarse CSI feedback on the narrow data pipe of PUCCH*
- Coarse P-CSI is a “stay alive” message, the target is not PDSCH link adaptation
  - *P-CSI is quickly replaced with more detailed A-CSI report as soon as data arrives in DL buffer*
  - *A-CSI is available a short while (typically 6-15 ms) after the UE starts being scheduled*

Codebook subsampling

- In previous releases codebook subsampling has been used
  - For larger number of ports (12/16,..) , the technique of codebook subsampling for P-CSI reporting may create problems due to the narrow beam widths and is not scalable when the number of ports increase further
- Codebook subsampling design for FD-MIMO
  - Requires high standardization effort due to the many different configurations
    - N1,N2,O1,O2,Config,PUCCH mode

Observations

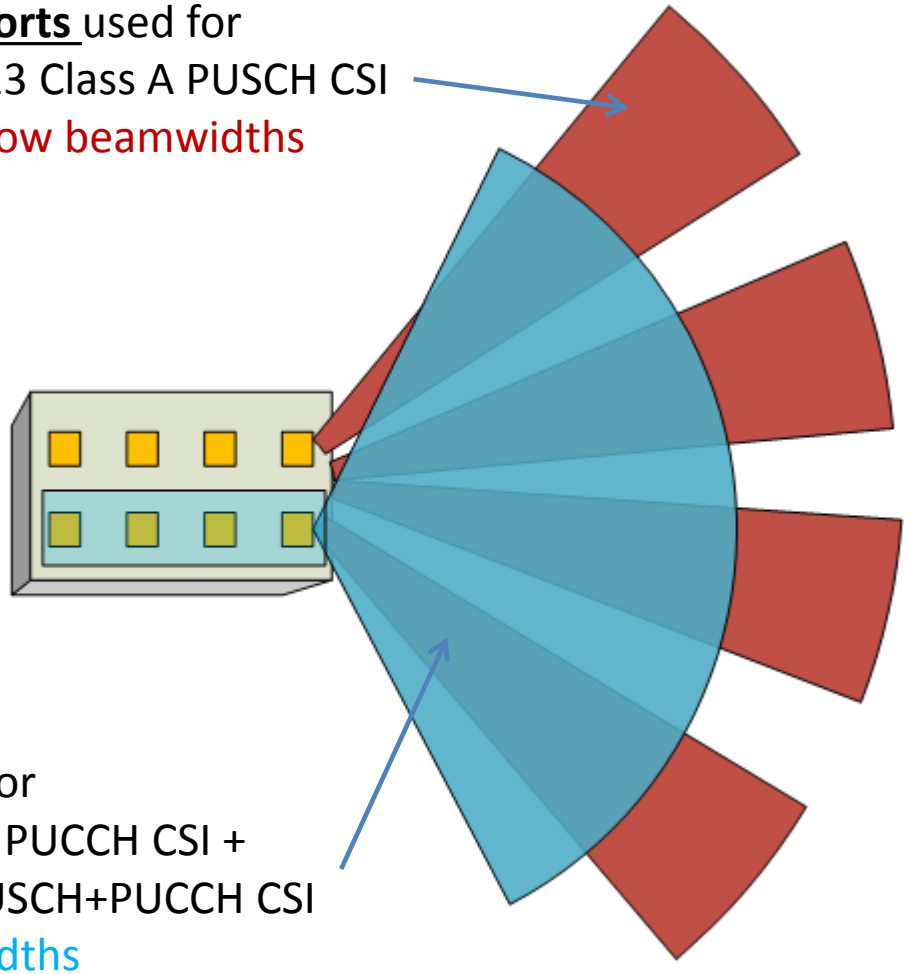
- For most of the time during 24 hrs, an eNB does not have any UE to schedule
  - And consequently, there is no need to trigger A-CSI report
- An eNB/AAS with 12,16 TXRUs will consume significantly more energy than current eNBs
  - Higher OPEX for operators is expected
- Currently no way to power down TXRUs when no UE is scheduled
  - Since CSI-RS needs to be transmitted from all 12/16 ports, periodically

Proposal

- For Class A P-CSI reporting on PUCCH, the UE measures and reports CSI based on the {2,4,8} CSI-RS ports of the first aggregated CSI-RS resource
  - Using legacy codebooks, CSI reporting modes and procedures
- For Class A A-CSI reporting on PUSCH, the UE measures and reports CSI on {8,12,16} CSI-RS ports based on Rel.13 Class A CSI feedback design

Illustration

<u>16 ports</u> used for
Rel.13 Class A PUSCH CSI
Narrow beamwidths



<u>8 ports</u> used for
Rel.13 Class A PUCCH CSI +
Legacy UEs PUSCH+PUCCH CSI
Wide beamwidths

Benefits of the proposal

- **eNB energy consumption: Reduced.**
  - If there is no data to transmit in the cell, the TXRUs used only for A-CSI can be powered down, and still CSI-RS measurements and P-CSI feedback can be obtained for served UEs.
    - The importance of this will be even larger if up to 32 ports is specified in Rel.14
  - Note that also legacy terminals will measure CSI on a subset of the 12/16 CSI-RS ports.
  - CRS/PDCCH/PBCH/PSS/SSS can also be transmitted using the same subset of antenna ports as those used for legacy terminals.

- **UE complexity and power consumption: Reduced.**
  - No need to measure and perform codebook search for more than 8 ports for the periodic reporting.
  - The 12/16 ports measurements using 2D codebook are only needed for A-CSI, when there is actual data to receive.
    - The importance of this will be even larger if up to 32 ports is specified in Rel.14
  - Existing P-CSI measurement and feedback implementation that are already in place for legacy terminals can be re-used.
  - With MR enabled, the A-CSI reporting becomes even more efficient since a single subframe of 8/12/16/16+ measurement is needed.

- **Standardization effort: Very small.**
  - No need to discuss and specify P-CSI details such as codebook subsampling for different configurations

- **Robustness: Increased**
  - Fewer measured ports and legacy codebooks effectively imply wider beams for P-CSI which gives robustness compared to the narrow beams
  - Subsampling a 2D codebook of a larger number of ports may require spreading UCI across more than two subframes which jeopardize robustness due to dependencies and error propagation

- **RAN4 Testing: No new tests needed**
  - No need for new P-CSI tests as legacy P-CSI is used for EB/FD-MIMO

Performance

Performance Comparison for 2x3 port layout case

Reference resource utilization	50%			
	3D-UMi		3D-UMa	
	P-CSI with subsampled 2D Codebook	P-CSI with subsampled Rel10 8Tx Codebook	P-CSI with subsampled 2D Codebook	P-CSI with subsampled Rel10 8Tx Codebook
Cell edge throughput [bps/Hz/user]	0.473	0.472	0.421	0.420
Mean User Throughput [bps/Hz/user]	2.30	2.28	2.10	2.08
Cell edge gain	0%	-0.22%	0%	-0.22%
Mean user throughput gain	0%	-0.76%	0%	-0.80%

Performance Comparison for 4x2 port layout case

Reference resource utilization	50%			
	3D-UMi		3D-UMa	
	P-CSI with subsampled 2D Codebook	P-CSI with subsampled Rel10 8Tx Codebook	P-CSI with subsampled 2D Codebook	P-CSI with subsampled Rel10 8Tx Codebook
Cell edge throughput [bps/Hz/user]	0.528	0.527	0.406	0.405
Mean User Throughput [bps/Hz/user]	2.370	2.344	2.071	2.046
Cell edge gain	0%	-0.27%	0%	-0.24%
Mean user throughput gain	0%	-1.08%	0%	-1.21%

- *Using legacy P-CSI instead of a newly designed subsampled 2D codebook based P-CSI implies less than 1.21% performance loss in both mean and cell edge user throughput.*
- *The design of the subsampled 2D codebook for P-CSI is given in Appendix 2.*

Concluding proposal

- For Class A P-CSI reporting for on PUCCH, the UE measures and reports CSI based on the {2,4,8} CSI-RS ports of the first aggregated CSI-RS resource
  - Using legacy codebooks, CSI reporting modes and procedures

Appendix 1

Simulation parameters	
Carrier frequency	2 GHz
Bandwidth	10 MHz
Scenarios	3D UMi 200m ISD, 3D UMa 500m ISD
Antenna Configurations	4x3 with 2x1 virt. to 2x3, tilts: 130° (UMi) 122° (UMa) 8x2 with 2x1 virt. to 4x2, tilts: 130° (UMi) 122° (UMa
Cell layout	1 vertical sector per azimuthal sector, 57 azimuthal sectors in total
Wrapping	Radio distance based
UE receiver	MMSE-IRC
CSI periodicity	A-CSI triggered every 5ms, 20ms for P-CSI
CSI delay	5 ms
CSI mode	PUSCH Mode 3-2, PUCCH Mode 1-1 submode 2
Outer loop Link Adaptation	Yes, 10% BLER target
UE noise figure	9 dB
eNB Tx power	41 dBm (UMi), 46 dBm (UMa) PDSCH corresponding to Rel-10 P-CSI is transmitted at reduced power, proportional to number of CSI-RS ports.
Traffic model	FTP Model 1, 500 kB packet size
UE speed	3 km/h
Scheduling	Proportional fair in time and frequency
CRS interference	Not modeled. Overhead accounted for 2 CRS ports.
DMRS overhead	2 DMRS ports
CSI-RS	Overhead accounted for. Channel estimation error modeled.
Codebook	2D Grid of Beams based on DFT
HARQ	Max 5 retransmissions
Antenna spacing	0.8 lambda in vertical, 0.5 lambda in horizontal
Handover margin	3 dB

Appendix 2: 2D Codebook Subsampling Design

- *Subsampling of the 2D codebook for P-CSI is designed such that it results in the same payload (total of 4 PMI bits) as for legacy PUCCH.*
- For 2x3 port layout case:
  - $N_1 = 2, N_2 = 3$*; PUCCH specific oversampling factors are* $O_1 = 1, O_2 = \frac{4}{3}$*; Results in 3 bits for* i_1
  - *1 bit for* i_2
- For 4x2 port layout case:
  - $N_1 = 4, N_2 = 2$*; PUCCH specific oversampling factors are* $O_1 = 1, O_2 = 1$*; Results in 3 bits for* i_1
  - *1 bit for* i_2