3GPP TSG-RAN WG1#82bis R1-155679

Malmö, Sweden, 5th - 9th October 2015

ERICSSON

SOURCE: ERICSSON

TITLE: CODEBOOK SUBSET RESTRICTION FOR CLASS A FD-MIMO

AGENDA ITEM: 7.2.4.3.1

DOCUMENT FOR: DECISION

CODEBOOK SUBSET RESTRICTION (CBSR)

- Codebook subset restriction limits the PMIs a UE includes with calculating CSI feedback.
  - Best performing PMI subsets can vary according to deployment scenarios and antenna configurations
  - Restricting PMIs that UE reports to these subsets improves performance
  - Has been supported for all LTE codebooks since Rel-8
- Codebook subset restriction does not reduce PMI overhead
  - Subset restriction typically targets individual PMIs, which are generally not enough to reduce overhead
  - Codebook subsampling is used for this purpose, where many PMIs are systematically removed from a codebook.

BACKGROUND: CLASS A CODEBOOK STRUCTURE

- For each of [8], 12 and 16 Tx ports, a precoding matrix $\boldsymbol{W}$ in the codebook is represented as (R1-154861):

$$\boldsymbol{W} = \boldsymbol{W}_1 \boldsymbol{W}_2$$

where:

- $\boldsymbol{W}_1 = \begin{pmatrix} \boldsymbol{X}_1 \otimes \boldsymbol{X}_2 & 0 \\ 0 & \boldsymbol{X}_1 \otimes \boldsymbol{X}_2 \end{pmatrix}$, $\boldsymbol{W}_2$ FFS
- $\boldsymbol{X}_1$ is a N_1xL_1 matrix with L_1 column vectors being an O_1x oversampled DFT vector of length N_1: $\boldsymbol{v}_{l_1} = \begin{bmatrix} 1 & e^{\frac{j2\pi l_1}{N_1 O_1}} & \dots & e^{\frac{j2\pi(N_1-1)l_1}{N_1 O_1}} \end{bmatrix}^t$
- $\boldsymbol{X}_2$ is a N_2xL_2 matrix with L_2 column vectors being an O_2x oversampled DFT vector of length N_2: $\boldsymbol{v}_{l_2} = \begin{bmatrix} 1 & e^{\frac{j2\pi l_2}{N_2 O_2}} & \dots & e^{\frac{j2\pi(N_2-1)l_2}{N_2 O_2}} \end{bmatrix}^t$
- N_1 and N_2 are the numbers of antenna ports per pol in 1st and 2nd dim.
- FFS whether to select different beams (e.g. different X1 or X2) for the two pols
- FFS column selection from KP applied to W_1

- (Notation from R1-154861 updated, clarifying beam indexing in $\boldsymbol{X}_1$ and $\boldsymbol{X}_2$)

l_1 and l_2 indicate each possible direction for beams v_{l_1} and v_{l_2}

REL-10 CBSR SIGNALING OVERHEAD

- CBSR restricts entire codebooks in bitmap fashion
  - Rel-10 8 port codebook uses 109 bits to signal CBSR
    - i1 and i2 restrictions are signaled independently
    - Each value of i1 for each layer where i1 is used is independently restricted, resulting in 56 bits to restrict i1
    - Each value of i2 for each layer where i2 is used is independently restricted, resulting in 53 bits to restrict i2.

FD-MIMO CBSR SIGNALING OVERHEAD

- FD-MIMO arrays tend not to need significantly different amounts of cophasing or beam selection than Rel-10/12
  - The number of i2 bits for each layer should be at most those in Rel-10
    - Therefore, it seems likely that no more than 53 bits would be needed for i2
  - Therefore, the Rel-10 mechanism to signal i2 can be reused for FD-MIMO, e.g. when its overhead is not too large relative to i1 restriction
- FD-MIMO arrays have 2D i1 (i.e. corresponding to (l_1, l_2) and an $\boldsymbol{X}_1 \otimes \boldsymbol{X}_2$), resulting in many more values of i1
  - If $O_1 = O_2 = 4$ times oversampling is used, then a 4x2 port layout could have $O_1 N_2 O_2 N_2 = 4 \cdot 4 \cdot 4 \cdot 2 = 128$ codewords per layer
  - If all 8 layers are restricted, i1 requires $8 \cdot 128 = 1024$ bits, leading to a large overhead even for RRC signaling
  - If 8 times oversampling is used, the overhead is very large: 4096 bits

Extending existing CBSR to FD-MIMO can require large RRC overhead

FD-MIMO CBSR WITH INDEPENDENT AZIMUTH AND ELEVATION RESTRICTION

- Restrict l_1 and l_2 independently
  - This assumes entire azimuths or elevations should be restricted, resulting in fairly coarse control
  - UE maps restricted i1 and i2 values from l_1 and l_2
    - A W1 or W2 matrix is restricted if its i1 or i2 corresponds to either l_1 or l_2
- Alt 1: Restrict l_1 and l_2 independently on a per-layer basis
  - $8 \cdot (4 \cdot 4 + 4 \cdot 2) = 192$ bits would be needed for i1 restriction
  - Rel-10 i2 restriction approach could be reused
    - If number of i2 bits is similar to Rel-10, roughly 50 bits could be needed for i2
    - If the total number of i2 bits is half that of Rel-10, roughly 25 bits are needed.
  - **Roughly 220-250 bits needed in total**
- Alt 2: Restrict l_1 and l_2 independently; restrictions apply to all layers
  - In addition to coarse 2D beam control, differences in behavior across rank can't be exploited
  - $(4 \cdot 4 + 4 \cdot 2) = 24$ bits would be needed for i1 restriction
  - i2 restriction should be simplified to indicate rank only
    - 8 bits are used to indicate if each of the 8 layers is used or not
  - **32 bits needed in total**

Restricting azimuth and elevation independently may allow low RRC overhead, but is too limiting

FD-MIMO CBSR WITH 2D BEAM RESTRICTION

- Restrict individual 2D beams (l_1, l_2) across all layers
  - Fine control of 2D beams to match the deployment scenario and eNB antenna configuration is possible.
  - i1 restrictions are directly signaled
    - A W1 matrix is restricted if its i1 corresponds to (l_1, l_2)
      - Restriction applies to all layers
    - Same behavior as Rel-10, except i1 restriction is not independent per layer.
  - $4 \cdot 4 \cdot 4 \cdot 2 = 128$ bits would be needed for i1 restriction
  - Rel-10 i2 restriction approach could be reused
    - Rank restriction can be indicated by i2 restriction
    - If number of i2 bits is similar to Rel-10, roughly 50 bits could be needed for i2
    - If the total number of i2 bits is half that of Rel-10, roughly 25 bits are needed.
  - **Roughly 160-180 bits in total**

Restricting azimuth and elevation jointly with each restriction across all layers has enough flexibility and acceptable RRC overhead

FD-MIMO CLASS A CODEBOOK SUBSET RESTRICTION PROPOSAL

- Codebook subset restriction restricts individual 2D beams across all layers
  - Restrictions on the W1 and W2 matrices in the codebook that can be used for PMI feedback by the UE are configured via RRC signaling
    - Each state of i1 (indicating W1) can be independently restricted across all layers
      - Each i1 restriction applies to all layers
      - The number of bits for i1 restriction is e.g. $O_1 N_1 O_2 N_2$
    - Each state of i2 (indicating W2) is independently restricted for each layer
      - Same methodology as Rel-10 is used
        - The number of bits for CBSR for i2 is $\sum_{r=1}^{8} i_2^r$, where i_2^r is the number of bits for W2 for a given layer
- The number of PMI bits does not vary according to restricted subsets of W1 and W2 matrices
  - Same approach as for Rel-8 – Rel-12 codebook subset restriction

ERICSSON