Joint Processing Multi-ABS MIMO – Feedback Proposals

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Purpose: Discussed and Approval

Background

- We investigate several methods for rank-1 computation and feedback for Multi-BS joint processing (Co-MIMO and CL-MD)
- We show that feedback of independent PMI per BS is much worse than methods that compute and feed back the global principal joint singular vector (JSV) of all collaborating BS antennas
- We propose several classes of feedback algorithms:
  - Analog and Compressed Analog
  - Joint codebook
  - Hybrid
- Details and text proposal are in C80216m-09_1360r1

Computation of the JSV

The optimal solution per subcarrier is given by a closed form formula

$$v = h_1^* \cos\theta + h_2^* \sin\theta \; e^{j\phi}$$

where h_i i=1,2 is the i'th row of H - the 2x(MN) global DL channel between the MS and all M collaborating BS (each with N antennas).

$$e^{j\phi} = \frac{h_2^* h_1}{| h_2^* h_1 |} \qquad \tan 2\theta = \frac{2 | h_2^* h_1 |}{| h_1 |^2 - | h_2 |^2}$$

Mobiles with 4 antennas can use the formula given in C80216m-09_1344

The formula is general and works for any number of BS and antenna configuration

Compressed Form for Correlated Antennas (CJSV)

When the BS antennas are correlated it's possible to reduce feedback overhead by parameterizing the feedback.

For example, if the BS uses a closely spaced array the rank-1 feedback can be represented by a steering array with one real phase parameter.

The resulting rank-1 feedback structure for 3 collaborating BS is

$$[\exp(j*(0:N-1)*\Phi_1) \quad \alpha\exp(j*(0:N-1)*\Phi_2) \quad \beta\exp(j*(0:N-1)*\Phi_3)]$$

with 3 real parameters Φ_i , the steering array phases, and two complex parameters

Analog Feedback

1. We map the MxN complex numbers to MxNxL subcarriers using AM and repetition-L coding

2. Compressed Form – we map the real (phase) values to subcarriers using PM and the complex weights using AM. Repetition-L coding is used as well

Repetition coding is capacity achieving at low SNR

Joint-CB

- Using the JSV we can find the optimal PMI for each group of antennas corresponding to one BS (A PMI search independently per-BS can be done as well but is suboptimal as in local vs. global maximum).

- In the second stage we combine the different PMI by usage of potentially different size codebook. For example, for 3 collaborating BS each with 4 antennas we need a 3 antenna codebook to combine the 3 4-antenna PMI. Alternatively we can use 2-antenna CB to sequentially combine the PMI.

- The usefulness of calculating the JSV and searching PMI with respect to it is clearly seen. Otherwise an optimal PMI search can not be implemented due to extremely high search complexity (three 6bit +two 3bit PMI for 3 4-antenna collaborating BS).

Hybrid

- This approach draws on the fact that most information of a rank-1 precoder lies in the phase of the elements.
- The JSV is ‘stripped’ of amplitude information and only the phases are sent with analog PM. This is a constant modulus feedback.
- The amplitudes are quantized to one bit per element and optionally sent digitally.

Simulation

- 3 collaborating BS serve 3 cell-edge users using MUZF.
- Explicit DL and UL channel modeling using SCM Urban Macro
- Users are chosen randomly
- Rest of interference + noise is modeled as AWGN with SNR between 0 and 10dB.

Results for 4-lambda spaced Cross-Pols

Antenna Configuration		DL SNR [dB]		
		0	5	10
Two 4-lambda spaced cross-pols SE Ratio Relative to independent per BS 6bit PMI	Joint Singular Vector (JSV)	2.37	2.24	2.18
	JSV @ 0dB - With UL Co-MIMO	2.27	2.13	2.07
	JSV @ 0dB	2.00	1.89	1.82
	JSV – EwQ (2A4P)	2.29	2.16	2.10
	JSV – EwQ (1A4P)	2.16	2.04	1.96
	JSV – EwQ (1A2P)	1.94	1.83	1.76
	Joint CB with 16e	1.88	1.78	1.70
	Joint CB with 16m	1.68	1.58	1.50
	Joint CB with 2bit subset	1.61	1.53	1.45
	Joint CB with 1bit subset	1.39	1.32	1.25

Cont. Results Relative to Joint CB with 16m

			Percent Gain		
Feedback Mechanism	**Total Bits**	**Total Subcarriers @ 12bits per SFBCH**	**DL SNR [dB]**		
			0	**5**	**10**
Joint Singular Vector (JSV)	N/A	12	41	42	45
JSV @ 0dB – Rep 3	N/A	36	35	35	38
JSV @ 0dB	N/A	12	19	20	21
JSV – EwQ (2A4P)	72	180	36	37	40
JSV – EwQ (1A2P)	36	90	15	16	17
Joint CB with 16e	24	60	12	13	13

Results for lambda/2 spaced Vertical-Pols

Antenna Configuration		**DL SNR [dB]**		
		0	**5**	**10**
Four lambda/2 spaced vertical-pols SE Ratio Relative to independent per-BS 6bit PMI	Joint Singular Vector (JSV)	1.99	1.91	1.91
	JSV @ 0dB - With UL Co-MIMO	1.86	1.77	1.74
	JSV @ 0dB	1.59	1.52	1.49
	JSV @ 0dB – Rep 2	1.79	1.71	1.67
	Compressed Joint Singular Vector	1.92	1.83	1.82
	CJSV @ 0dB	1.40	1.36	1.33
	CJSV @ 0dB – Rep 2	1.63	1.56	1.53
	CJSV @ 0dB – Rep 3	1.72	1.65	1.62
	CJSV – EwQ (4P2A4P)	1.84	1.76	1.73
	CJSV – EwQ (4P2A2P)	1.78	1.71	1.68
	CJSV – EwQ (3P1A2P)	1.51	1.45	1.40
	Joint CB with 16e	1.79	1.72	1.69
	Joint CB with 16m	1.50	1.45	1.41

Cont. Results Relative to Joint CB with 16m

			Percent Gain		
Feedback Mechanism	**Total Bits**	**Total Subcarriers @ 12bits per SFBCH**	**DL SNR [dB]**		
			0	**5**	**10**
Joint Singular Vector	N/A	12	33	32	35
JSV @ 0dB – Rep 3	N/A	36	24	22	23
JSV @ 0dB	N/A	12	6	5	6
Compressed JSV	N/A	5	28	26	29
CJSV @ 0dB – Rep 3	N/A	15	15	14	15
CJSV @ 0dB – Rep 6	N/A	30	22	21	23
CJSV – EwQ (4P2A4P)	24	60	23	21	23
CJSV – EwQ (4P2A2P)	20	50	19	18	19
Joint CB with 16e	24	60	19	19	20

Conclusions

- Joint CB approach can close the gap to uncompressed or compressed unquantized feedback. The ratio of bits per analog complex element is $\frac{6M+3(M-1)}{4M} = 2\,(M=3)$ and could theoretically be reduced with optimized codebooks for NM antennas
- Usage of 16e 2-antenna codebook for Joint CB provides better performance due to the amplitude variation as opposed to the 16m constant modulus codebook.
- Results shown here assume the knowledge of the optimal rank-1 precoder. Without that knowledge performance deteriorates. Actual computation is vendor specific.
- Correlated antennas at the BS enable much reduced feedback using CJSV with a subcarrier ratio of $\frac{M+M-1}{NM} \approx \frac{2}{N}$ for M BSs each with N antennas.
- Analog feedback and its compressed version provides still better tradeoff between DL performance and UL overhead and is simpler for a MS to implement.