Agenda item: 6.3.1.1

Source: Samsung

Title: Performance evaluation of CoMP dynamic cell selection in scenario 2 (homogeneous networks)

Document for: Discussion and decision

1   Introduction

In 3GPP RAN #50 meeting, a revised CoMP study item was agreed for Release 11 [1]. In 3GPP RAN1 #63bis, CoMP study item was initiated. Some high level views and evaluation methodology were discussed.

The schedule for CoMP evaluation was decided in RAN 1 #63bis as follows

- Phase 1
  - Homogeneous network with high Tx power RRHs
  - Starts now
  - Aim to conclude in RAN1#65
- Phase 2
  - "Heterogeneous network with low power RRHs within the macrocell coverage", and "network with low power RRHs within the macrocell coverage where the transmission/reception points created by the RRHs have the same cell IDs as the macro cell"
  - Starts after RAN1#64

In 3GPP RAN1 #64, the evaluation methodology for both DL and UL has been finally agreed [2-3] and a new TR document was created to incorporate RAN1 decisions on CoMP study item. The skeleton of that TR was endorsed in [4]. Some preliminary Phase 1 simulation results were discussed. A target date of April 15 was agreed for companies to submit their updated Phase 1 results. In this contribution, we provide some updated simulation results to some of our previous Phase 1 CoMP evaluation [7]. The major difference with [7] is the consideration of non-ideal CSI-RS and DM-RS channel estimation and the evaluations for a larger scope of resource utilizations.

CoMP JP has been categorized into Dynamic Cell Selection and Joint Transmission. This contribution focuses on the Dynamic Cell Selection. Performance of Joint Transmission is investigated in the companion contribution [5,8]. Section 2 describes the Dynamic Cell Selection scheme under consideration and Section 3 provides evaluation results for both full buffer and non-full buffer.

2   Dynamic Cell Selection combined with ON-OFF power control

Dynamic cell selection with ON-OFF power control is a relatively simple scheme inspired by [6] that doesn't rely on spatial domain interference mitigation as in JT or coordinated beamforming. It works as follows.

Overall operation

The scheme combines a dynamic cell selection phase and a dynamic power control phase. As illustrated in Figure 1, the best selected cell (dynamic cell selection) is assumed to be reported every cell_ID_report_period msec while the CQI report to operate the power control is performed every CQI_report_period msec.
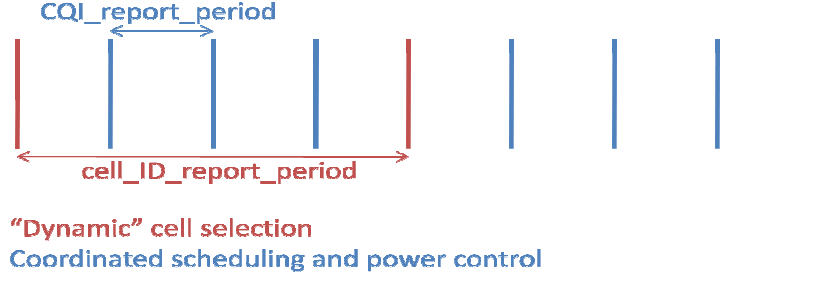
Figure 1. Overall operation of dynamic cell selection combined with dynamic ON-OFF power control.

In the simulations performed in Section 3, we assume for simplicity that cell_ID_report_period and CQI_report_period rate the same and are fixed to 5 msec.

Step 1: "dynamic" cell selection

UE reporting:

For a given user q, determine and report the ID of the serving cell and the dominant interfering cell based on a wideband throughput measure

- Serving cell: $i_q^* = \arg max_{i \in M_q} \sum_{l=1:RI_i} log_2(1 + SINR_{w,i,q,l})$ (assuming wideband PMI)
- The dominant interfering cell: $I_q^* = \arg max_{j \in M_q \setminus i_q^*} \sum_{l=1:RI_j} log_2(1 + SINR_{w,i,q,l})$

where $SINR_{w,i,q,l}$ is a wideband SINR for codeword l and M_q is the CoMP measurement set of user q. At this stage, the power in all cells is assumed to be always turned ON when cell selection is performed. The report of the serving cell and the dominant interfering cell is done every cell_ID_report_period.

Note that in the evaluations, only the dominant interfering cell is reported for a CoMP UE irrespectively of the CoMP threshold (its CoMP measurement set size).

Step 2: Coordinated scheduling and power control

UE reporting:

For a given CoMP user q and its serving cell i_q^*, compute and report two sets of CQI information

- $\{CQI_{k,i_q^*,q,no\ CoMP}, RI_{i_q^*,q,no\ CoMP}, PMI_{k,i_q^*,q,no\ CoMP}\}$ set refers to the set of CQIs (one or two) computed assuming SU-MIMO transmission in subband k with the selected subband PMI, wideband RI and full transmit power in all interfering cells.
- $\{CQI_{k,i_q^*,q,CoMP}, RI_{i_q^*,q,CoMP}, PMI_{k,i_q^*,q,CoMP}\}$ set refers to the set of CQIs (one or two) computed assuming SU-MIMO transmission in subband k with the appropriate RI/PMI and transmit power on subband k in node I_q^*, denoted as S_{k,I_q^*}, fixed to 0 (i.e. $S_{k,I_q^*} = 0$).

A non-CoMP UE would report only $CQI_{k,i_q^*,q,no\ CoMP}, RI_{i_q^*,q,no\ CoMP}, PMI_{k,i_q^*,q,no\ CoMP}$ as in Rel. 10. The report of the sets of CQI is done every CQI_report_period. We assume a PUSCH 3-2 like reporting mechanism where subband PMI and subband CQI are reported. Given the reports of the $CQI_{k,i_q^*,q,no\ CoMP}, RI_{i_q^*,q,no\ CoMP}, PMI_{k,i_q^*,q,no\ CoMP}$ and $CQI_{k,i_q^*,q,CoMP}, RI_{i_q^*,q,CoMP}, PMI_{k,i_q^*,q,CoMP}$, the feedback overhead for a CoMP UE is doubled compared to a non-CoMP UE.

eNB centralized scheduling:

Based on $CQI_{k,i_q^*,q,no\ CoMP}$ and $CQI_{k,i_q^*,q,CoMP}$, a centralized coordinated scheduler (operating over a set of 9 cells) and binary power control is operated where for each RB in every cell, the scheduler identifies the best pair (allocated power,scheduled UE) in order to maximize a weighted sum-rate accounting for fairness among UEs. SU-MIMO is

assumed such that maximum one user can be allocated per RB per cell. The ON-OFF power control is performed at the RB level.

We note the following two important assumptions in the evaluations:

- The power that is turned off is not reallocated to other RBs. Hence the total power consumed by performing DCS is lower than the one used in the non-CoMP case.
- A CoMP UE requests to turn off one single cell.

3 Performance evaluation

In section 3.1 and 3.2, we provide full-buffer and non-full buffer results, respectively. The results assume the following DL overhead:

- 4 subframes out of 10 have an overhead of 3 OFDM symbols (PDCCH) + 2 CRS ports outside PDCCH region + DMRS and 6 subframes out of 10 have an overhead of 2 OFDM symbol for PDCCH + DMRS (MBSFN subframes).

3.1 Full-buffer evaluation

Table 1 Full-buffer performance of 2x2 CoMP DCS SU-MIMO vs. Rel. 10 SU-MIMO as a function of the CoMP threshold (1, 3, 5, 10, 15 dB).

2x2 K=10	Cell avg.		Cell edge		Resource utilization
	Absolute throughput [bps/Hz/cell]	Relative gain	Absolute throughput [bps/Hz/user]	Relative gain	
No DCS	2.097	0.00%	0.071	0.00%	100%
1dB	2.097	0.00%	0.071	0.00%	99.8%
3dB	2.099	0.09%	0.071	0.79%	98.6%
5dB	2.090	-0.35%	0.072	1.96%	97.3%
10dB	2.079	-0.84%	0.074	4.97%	95.6%
15dB	2.144	2.25%	0.074	4.97%	95.6%

In the full buffer case, we observe that:

- DCS provides a minor cell-edge improvement of 5% over Rel. 10.
- The resource utilization decreases from 100% to 95% as the CoMP threshold increases from 0 dB to 15 dB as a consequence of turning off the power on some RB.

3.2 Non-full buffer evaluation

In the non-full buffer case, we run FTP traffic model with K=5,4,3,2, corresponding to various resource utilizations in the non-CoMP (No DCS) case.

Table 2. Non-full-buffer performance of 2x2 CoMP DCS SU-MIMO vs. Rel. 10 SU-MIMO as a function of the CoMP threshold (1, 3, 5, 10, 15 dB) for K=5.

2x2 K=5	Cell avg.		Cell edge		Resource utilization
	Absolute throughput [bps/Hz/cell]	Relative gain	Absolute throughput [bps/Hz/user]	Relative gain	
No DCS	1.230209	0.00%	0.127007	0.00%	59.4%
1dB	1.230209	0.00%	0.127934	0.73%	58.9%
3dB	1.228355	-0.15%	0.131643	3.65%	57.01%
5dB	1.23299	0.23%	0.136278	7.30%	54.1%
10dB	1.243187	1.06%	0.142767	12.41%	50.1%
15dB	1.24226	0.98%	0.142767	12.41%	50.01%

Table 3. Non-full-buffer performance of 2x2 CoMP DCS SU-MIMO vs. Rel. 10 SU-MIMO as a function of the CoMP threshold (1, 3, 5, 10, 15 dB) for K=4.

2x2 K=4	Cell avg.		Cell edge		Resource utilization
	Absolute throughput [bps/Hz/cell]	Relative gain	Absolute throughput [bps/Hz/user]	Relative gain	
No DCS	1.143065	0.00%	0.196537	0.00%	37.4%
1dB	1.143992	0.08%	0.198391	0.94%	37.1%
3dB	1.152336	0.81%	0.204417	4.01%	36.2%
5dB	1.143992	0.08%	0.212297	8.02%	34.2%
10dB	1.167169	2.11%	0.223421	13.68%	31.1%
15dB	1.151409	0.73%	0.223421	13.68%	31.1%

Table 4. Non-full-buffer performance of 2x2 CoMP DCS SU-MIMO vs. Rel. 10 SU-MIMO as a function of the CoMP threshold (1, 3, 5, 10, 15 dB) for K=3.

2x2 K=3	Cell avg.		Cell edge		Resource utilization
	Absolute throughput [bps/Hz/cell]	Relative gain	Absolute throughput [bps/Hz/user]	Relative gain	
No DCS	0.994735	0.00%	0.254942	0.00%	25.9%
1dB	0.993808	-0.09%	0.256518	0.62%	25.4%
3dB	1.022547	2.80%	0.264212	3.64%	24.5%
5dB	1.020693	2.61%	0.27441	7.64%	23.3%
10dB	1.009568	1.49%	0.288316	13.09%	21.3%
15dB	1.022547	2.80%	0.289243	13.45%	21.3%

Table 5. Non-full-buffer performance of 2x2 CoMP DCS SU-MIMO vs. Rel. 10 SU-MIMO as a function of the CoMP threshold (1, 3, 5, 10, 15 dB) for K=2.

2x2 K=2	Cell avg.		Cell edge		Resource utilization
	Absolute throughput [bps/Hz/cell]	Relative gain	Absolute throughput [bps/Hz/user]	Relative gain	
No DCS	0.694368	0.00%	0.317055	0.00%	10.2%
1dB	0.692514	-0.27%	0.317982	0.29%	10.15%
3dB	0.691031	-0.48%	0.325398	2.63%	9.93%
5dB	0.726815	4.67%	0.33745	6.43%	9.62%
10dB	0.735159	5.87%	0.35321	11.40%	9%
15dB	0.736086	6.01%	0.35321	11.40%	9%

For a CoMP threshold of 10dB, the evolution of the cell edge throughput as a function of the resource utilization for single-cell SU-MIMO and CoMP DCS is displayed in Figure 1.
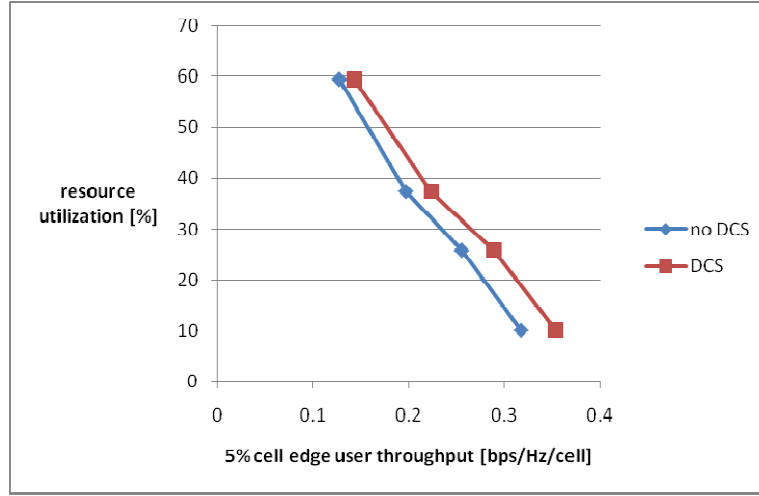

Figure 1. Evolution of the 5% cell edge throughput (x-axis) as a function of the RU (y-axis) for a CoMP threshold of 10dB

In the non-full buffer case, we observe that:

- DCS provides a moderate cell-edge improvement of 12% over Rel. 10 for a wide range of resource utilizations.
  - CoMP gain is larger in non-full buffer compared to full buffer.
  - DCS naturally exploits the fact that some RBs are turned off due to the lack of data in the buffer.
- DCS decreases the resource utilization factor (i.e. reduces the number of resources used to send the packets in the buffer) as it helps packets to be transmitted with a higher MCS level or higher transmission rank.

We note that further enhancements are possible in the following two areas

- Allocating the unused power to the scheduled RBs.
- Increasing the number of cells that a UE requests to turn off.

4 Conclusions

In this contribution, we perform CoMP Phase 1 evaluation and compare the performance of SU-MIMO with DCS with Rel. 10 SU-MIMO.

We observe that:
- In the full buffer case, DCS provides a minor cell-edge improvement of 5% over Rel. 10 in the full buffer case.
- In the non-full buffer case, DCS provides a moderate cell-edge improvement of 13% over Rel. 10 in the non-full buffer case.

We also identified some areas where further enhancements of the scheme are possible.

5 References

[1] RP-101425, "Revised SID Proposal: Coordinated Multi-Point Operation for LTE," 3GPP TSG RAN#50, Istanbul, Turkey, 7th – 10th December, 2010.

[2] R1-111125, "CoMP simulation assumptions," NTT DoCoMo, Taipei, Taiwan, 21st - 25th February 2011.

[3] R1-111121, "Text Proposal of Simulation Assumptions for Evaluation of UL CoMP," Alcatel-Lucent , Alcatel-Lucent Shanghai Bell, Taipei, Taiwan, 21st - 25th February 2011.

[4] R1-111167, "Skeleton TR36.819 v0.0.1," Samsung, Taipei, Taiwan, 21st - 25th February 2011.

[5] R1-111282, "Performance evaluation of CoMP JT for Scenario 2", Samsung, Barcelona, Spain, 9th - 13th May 2011.

[6] R1-090314, "Investigation on Coordinated Multipoint Transmission Schemes in LTE-Advanced Downlink," NTT DOCOMO, 3GPP TSG RANWG1 55bis, Jan. 2009.

[7] R1-111281, "Performance evaluation of dynamic cell selection in homogeneous networks", Samsung, Barcelona, Spain, 9th - 13th May 2011.

[8] R1-111464, "Performance evaluation of CoMP JT for Scenario 2", Samsung, Barcelona, Spain, 9th - 13th May 2011.

6 Appendix

Parameter	Values used for evaluation (Scenario 2)

Performance metrics	• Full buffer traffic: Cell capacity, Cell-edge (5%) user throughput
	• Non full buffer traffic: see Section A.2.1.3.2 in TR36.814
	  1. Cell throughput
	    ▪ Served cell throughput = total amount of data for all users / total amount of observation time / number of cells
	  2. 5% user throughput
	    ▪ User throughput = amount of data (file size) / time needed to download data

Deployment scenarios	Scenario 2: Homogeneous network with high Tx power RRHs • The central entity can coordinate 9 cells as a baseline (Reference layout is given in Appendix) • 5 clusters perform 9 cells cooperation, 2 clusters perform 6 cells cooperation. Results are collected over 57 cells.
Simulation case	Deployment scenarios 1, 2 Baseline: 3GPP-Case1
High power RRH Tx power (Ptotal)	46dBm in a 10MHz carrier
Number of UEs per cell	Full buffer traffic model: 10 for Homogeneous networks; dependent on the targeted resource utilization for non-full-buffer traffic model.
System bandwidth	10 MHz
Possible transmission schemes in DL	● SU-MIMO ● SU-MIMO with intra-eNB JP (DCS)-CoMP
Impairments modelling	Baseline timing error is 0us
Network synchronization	Synchronized
Number of antennas at transmission point	Macro and high Tx power RRH: 2 for FDD
Number of antennas at UE	2
Antenna configuration	For macro eNB and high power RRH, In priority order for each number of antennas: • 2 antennas 1. 1 column, cross-polarized: X Cross-polarized antenna configuration is also applied to the receiver.
Antenna pattern	For macro eNB and high-power RRH: 3D as baseline

eNB Antenna tilt	For macro eNB and high-power RRH: 15 degrees downtilt.
Antenna gain + connector loss	For macro eNB and high-power RRH: 14 dBi in 3GPP Case 1
Feedback scheme (CQI/PMI/RI)	Implicit feedback PUSCH 3-2 like feedback (subband PMI/CQI report, 5RB subband size) for both Rel-10 and CoMP Feedback overhead for CoMP UEs is doubled compared to Rel-10 UEs Feedback periodicity is 5 ms with 6 ms delay
Channel estimation	Non-ideal channel estimation on CSI-RS and DM-RS (MSE obtained from LLS evaluations) Feedback scheme based on Rel. 10 RI/PMI/CQI design
UE receiver	Mandatory: MMSE receiver model option1 in R1-11058
DL overhead assumption	4 subframes out of 10 have an overhead of 3 OFDM symbols (PDCCH) + 2 CRS ports outside PDCCH region + DMRS and that 6 subframes out of 10 have an overhead of 2 OFDM symbol for PDCCH + DMRS
Placing of UEs	Uniform distribution for homogeneous networks
Traffic model	Full buffer Non-full-buffer according to Section A.2.1.3.1 in TR36.814, with the following modifications: • Model 2 with file size of 0.5 Mbytes • Simulations are run for various K (for model 2) that lead to covering at least the range [10 - 70]% of RU (See A.2.1.3.2) in non-CoMP SU-MIMO, and the metrics described in A.2.1.3.2 are computed for each K (for model 2) value • The RU is computed over the entire network, i.e. the RU is the average of the RUs per transmission point
Backhaul assumptions	[point-to-point fiber, zero] latency and infinite capacity Optical fiber required to perform dynamic cell selection
Link adaptation	Non-ideal (CQI adjusted based on outer-loop control relying on ACK/NACK feedback. MCS allocated based on CQI_{CoMP} and $CQI_{no\ CoMP}$)