Rethink Possible

DL-MIMO Enhancement for 4Tx in Rel 11

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DL-MIMO Enhancement Options

- The objective of the E DL-MIMO study item is to improve the system performance of the 4 Tx case in the DL.
- This is a separate study item from CoMP and therefore we exclude any performance enhancement technique that would be otherwise covered in CoMP
- The main area of interest here are
  - A new codebook design
    - A dual codebook design is suggested
    - Outer codebook: matched to the longterm wideband characteristics of the channel
    - Inner codebook: can be either the old 4 Tx codebook from rel 8 or a new codebook entirely
  - Feedback Enhancement
    - Mode 3-2
    - MU-CQI and rank restricted feedback.

Codebook Enhancement

- The dual codebook structure was established in rel 10 for the 8 Tx system. It seems as though there is general agreement that the 4 Tx codebook should also follow a similar path with an outer wideband codebook, and an inner narrow band codebook. The separation of users for MU-MIMO can be done based on the outer codebook
- Outer codebook design
  - The outer precoders have a block diagonal or diagonal structure. The block diagonal structure is suited for cross-pol antenna configuration, whereas the diagonal structure is suited for a cross-pol as well as a co-pol antenna configuration. We have chosen a diagonal structure which is as follows:

$$p_i = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & e^{-j2\pi\frac{i-1}{N}} & 0 \\ 0 & 0 & 0 & e^{-j2\pi\frac{i-1}{N}} \end{bmatrix}$$

XX

$$p_i = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & e^{-j2\pi\frac{i-1}{N}} & 0 & 0 \\ 0 & 0 & e^{-j2\pi\frac{2(i-1)}{N}} & 0 \\ 0 & 0 & 0 & e^{-j2\pi\frac{3(i-1)}{N}} \end{bmatrix}$$

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$$i \in [1, \cdots, N]$$

  - N is the number of precoders in the codebook. We chose $N = 8$, i.e. a 3 bit codebook

- Inner codebook design
  - The 4 bit rel 8 4 Tx codebook
  - A new 4 – 7 bit Grassmannian codebook based on previous work by Robert Heath and David Love

Codebook Selection Algorithm

- The selection algorithm for the inner precoder is the same as before and is based on the receiver type:
  - Linear receiver (MMSE variants) maximization of post receiver SINR
  - MLD receiver maximization of OL Shannon Capacity

- For the outer precoder we looked into two different search:
  - Exhaustive search based on all possible combinations of outer and inner codebook. This search algorithm is tedious and time consuming.
  - The second a perhaps a suboptimal search algorithm is based on the following criteria.

$$i = \arg\min_i \left(\det \left(\left\langle p_i^H H^H H p_i \right\rangle - \phi_{ideal} \right) \right) \text{where is average is a time-frequency average}$$

$$\phi_{ideal} \text{ for DIV} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad \phi_{ideal} \text{ for CLA} = \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \end{bmatrix} \quad \phi_{ideal} \text{ for ULA} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$

  - Simulation results show that the performance with this simpler search is is nearly the same as the optimal exhaustive search. Our results shown here use this simpler search algorithm for the outer precoder.

Simulation Scenarios

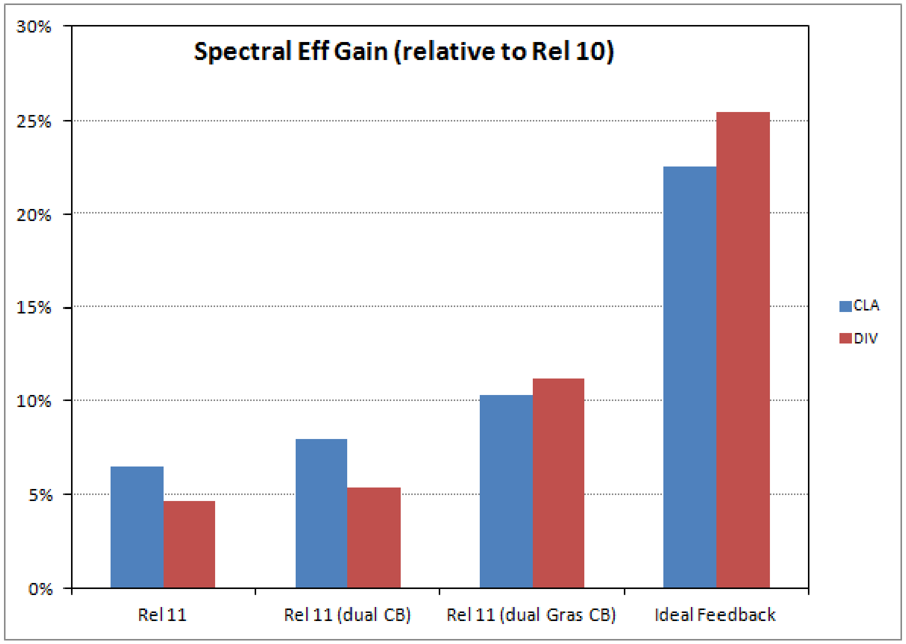
- For the purposes of understanding the benefits of various enhancements we consider the following cases:
  - Rel 10: 4Tx TM9 rel 8 codebook with PUSCH mode 3-1.
  - Rel 11: 4Tx TM9 rel 8 codebook with PUSCH mode 3-2.
  - Rel 11: 4Tx TM9 dual codebook with rel 8 codebook inner precoder with PUSCH mode 3-2.
  - Rel 11: 4Tx TM9 dual codebook with Grassmannian codebook with PUSCH mode 3-2.
  - Ideal Feedback: TM9 with Unquantized SINR feedback and unquantized precoder based on SVD+waterfilling.
    - Higher gains expected from this for MU-MIMO which is more sensitive to feedback quantization.

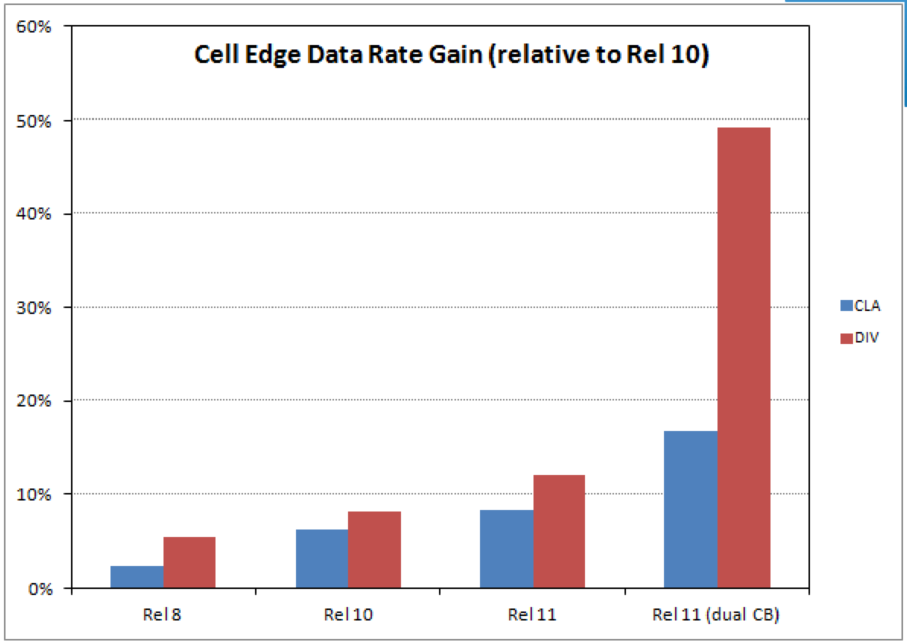
- For each of these cases we intend to model both full buffer and finite buffer traffic.

- The current set of results are based on SU MIMO. MU MIMO results will follow shortly.

Full Buffer SU-MIMO Performance

- The results are shown as gain in spectral efficiency and cell edge data rate relative to the rel 10 4 Tx case.
- Overall improvement is higher for the DIV 2X, although CLA 2X shows pretty good gains as well. The absolute numbers are still better for CLA 2X (with ideal feedback the performance is almost identical)

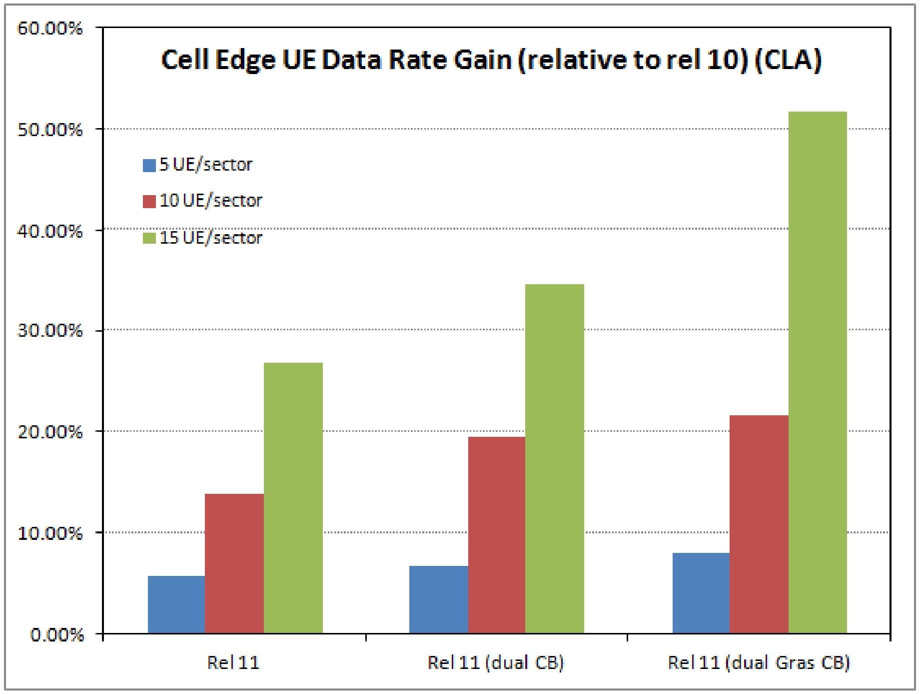


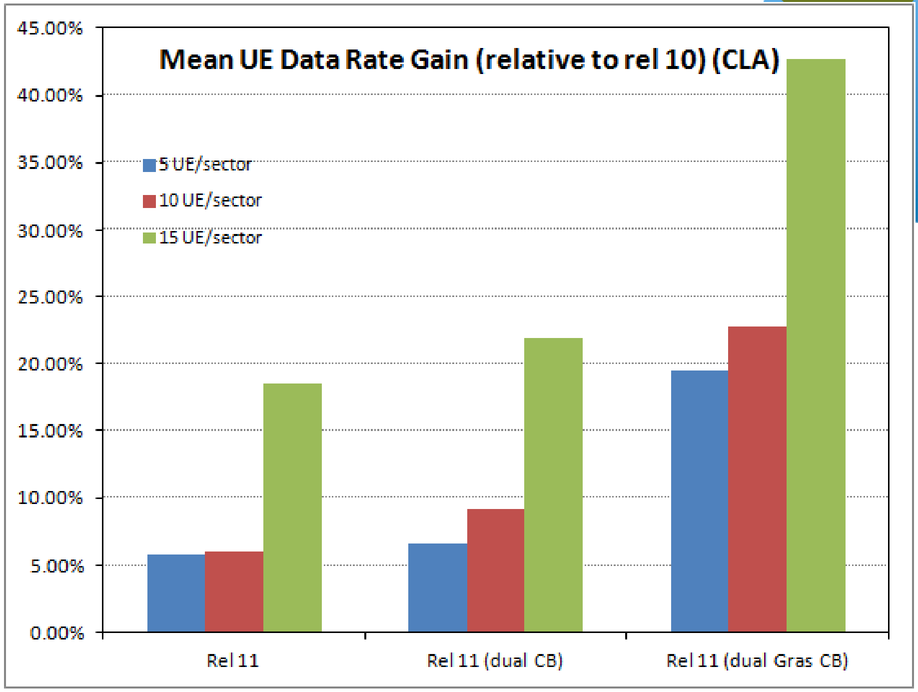


The Grassmannian codebook benefits the DIV 2X the most, although the gains for CLA 2X are not bad

Finite Buffer SU-MIMO Performance (CLA)

- For finite buffer simulations we model each UE to generate an average of 500 kbps of data traffic. The load is controlled by varying the number of UEs.

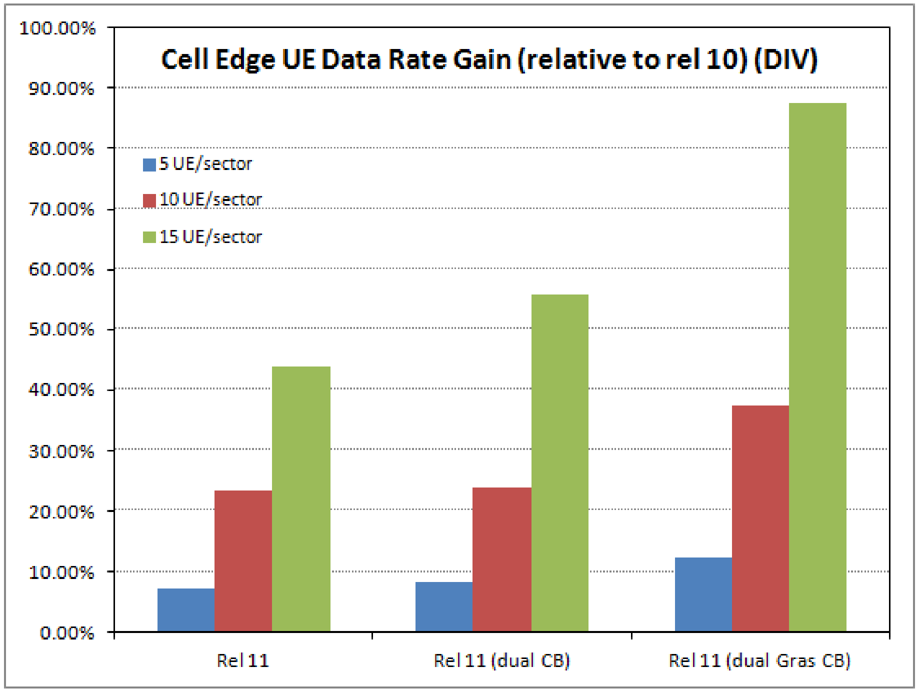


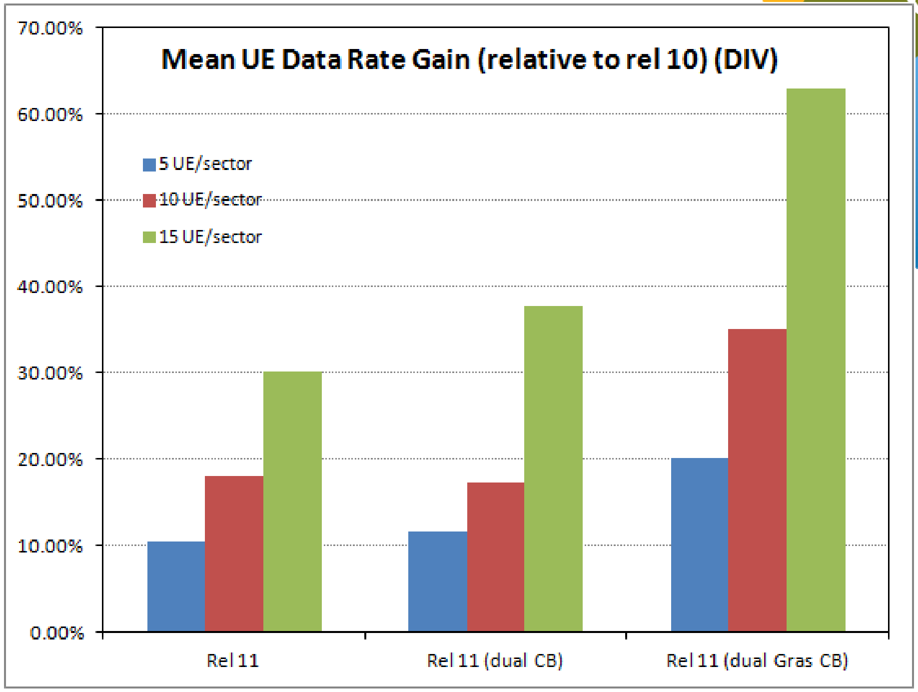


The gains are substantially higher than full buffer simulations. The gain from better codebook/feedback design goes up as the load increases

Finite Buffer SU-MIMO Performance (DIV)

- The gains from Grassmannian codebook design are more impressive in the case of DIV 2X.





With more enhanced feedback the throughput of each link is higher, which leads to a lower resource utilization i.e. lowered interference. Thus with improved codebook design and feedback we not only improve the throughput but also reduce the interference, this is why the improvement in data rate is much higher than full buffer simulations.

Conclusions

- We have done some preliminary work on the topic of E DL-MIMO and feel that there are codebook and feedback enhancements that should be included in rel 11 in order to improve the 4 Tx performance.
  - In general a dual codebook structure seems to be beneficial in the case of CLA-2X compared to DIV-2X. However we need to revisit this in the context of MU-MIMO

- The impact of various feature such as new codebook etc., are quite different in the case of finite buffer traffic when compared to full buffer traffic. This requires that under the E DL-MIMO study item we look at both full buffer and finite buffer traffic models in order to assess the potential gains of these enhancements.

- We need to have a systematic approach in the study item in order to determine where to invest our “feedback bits”
  - Codebook enhancements (dual codebook).
  - SU-CQI and MU-CQI enhancements.
  - Tradeoff between codebook size and feedback granularity.

Backup Slides

Simulation Assumptions

Parameter	Values
Carrier Frequency	2100 MHz
Channel Bandwidth	5 MHz
Number of UE/Sector	5 UE/Sector full buffer, variable for finite buffer
Inter Site Distance	500 m
Propagation Model	3GPP
Channel Model	SCM-E Urban Macro
Shadow Fading	Log normal with 8 dB Std Dev
In-building Loss	Outdoor UE with 0dB in building loss.
UE Speed	3 km/hour
Traffic Model	Full buffer Finite buffer :250 KB file size with exponential inter-arrival time of 2 sec
MIMO Mode	CL with SU-MIMO adaptive rank selection
Link Adaptation	CQI/RI feedback based
CSI Feedback Mode	PUSCH Mode 3-1/3-2 with 5 msec interval (outer codebook 25 msec)
Codebook	Rel 8 / Dual codebook with Rel 8 codebook/ Dual codebook with Grassmannian codebook
Receiver	MMSE with interference rejection
ENodeB Antenna	3GPP specific horizontal and vertical pattern and 15 degree downtilt.
ENodeB Antenna Gain	17 dBi
UE Antenna	Omni directional antenna with 2 cross-pol antenna elements
UE Antenna Gain	0 dBi
Channel Estimation	Realistic
Scheduler	Proportional fair with best effort. Frequency selective scheduling