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1 Introduction

It is well known [1] that multiple input multiple output (MIMO) $N_r \times N_t$ systems theoretically allow to significantly increase transmission capacities by a multiplexing gain factor of $\min(N_r, N_t)$. However, this result only stands for asymptotically high signal to noise ratio (SNR) values. Practically speaking, a minimal SNR of 15 dB is desirable to appreciate the rate increase; but this gain comes at the expense of an increased computational cost, of a denser embedded hardware (to fit in particular multiple antennas in a mobile terminal) and of an increased feedback requirement (the number of complex channel gains to be fed back grow along with $N_r \times N_t$).

In general, the performance of MIMO technologies in mobile cellular environments is limited mainly due to the interference limited nature of multi-cell technologies; most communications operate at a signal to interference plus noise ratio (SINR) less than 15 dB. In general, the performance of MIMO technologies in mobile cellular environments is limited, mainly due to the interference limited nature of multi-cell technologies. Most communications operate at a signal to interference plus noise ratio (SINR) less than 15 dB. LTE-A would be particularly impacted by this problem.

Assuming ideally that all serving base stations in the network are connected and operate on the network as a whole and not in their dedicated cells brings two significant advantages:

- Base stations can cooperate to limit interference, by exploiting beamforming techniques for instance.
- Base stations can even cooperate to increase the users' throughput, by *network MIMO* techniques. This is especially the case for cells which are controlled by the same eNodeB

Network MIMO comes of course along with a huge feedback increase which demands appropriate *feedback cost/MIMO efficiency* trade-offs. **As an initial discussion, the aim of this contribution is to point out some of main trade-offs that need to be taken into consideration when considering the cooperation between base stations.**

2 Capacity gain of Network MIMO

Consider the downlink of an OFDMA network, such as LTE-A network, with multiple users (M users deployed in the whole network) equipped with N_r antennas and as many as N base-stations each equipped with N_t antennas. The traditional approach is to minimize co-channel interference by isolating every cell from its neighbors, for example with classical beamforming techniques. However, the intricate nature particularly of urban environments, the impossibility to create interference-free zones and the non uniform distribution of users in neighbor cells can significantly limit the efficiency of the system. Alternatively, multicell cooperation is an effective means of co-channel interference mitigation and non-uniform distribution of the users in the cells can be efficiently treated, i.e. empty cells can lighten the loaded cell burden by providing additional space diversity.
Ideally the network MIMO principle is merely as simple as a broadcast MIMO system in which,

- the transmitter is the cooperative combination of all base stations, therefore composed of a large array of NN_t antennas,
- the receivers are the set of all user equipments (UE) independently of any "serving cell"[1].

As a consequence, the effective channel $\mathbf{H}_k$ between the large transmitter and a particular receiver k is of dimension $N_r \times NN_t$. As long as the total number of transmitting antennas (i.e. NN_t) is of the same order as the total number of receiving antennas (i.e. MN_r), the sum-rate capacity is that of classical broadcast MIMO channels, which is known to be achievable through the greedy dirty paper coding algorithm and which grows unbounded with the SNR.
However, network MIMO, comes along with a few practical complexity and spectral efficiency problems, which require to be traded-off with expected capacity returns. Those problems are developed in the following.

3 Limits and Trade-offs of Network MIMO

The important limiting factor to perform efficient network MIMO, over the complete network is the strong feedback constraint. Indeed, broadcast MIMO precoding is shown to be very sensitive to the quality of the channel state information [2]. In a network MIMO context, this uplink load may be prohibitive when N is large and may already be a wrong strategic choice for $N > 2$ or $N > 3$, since the uplink load would then be the bottleneck of the network-wide capacity.
For a given UE, it is likely that no more than a few base stations are in a small enough coverage range to provide effective performance gain. Moreover, assuming remote base stations do no cooperate, their interference level is in general too small to strongly impair the UE performance. The trade-off to be thoroughly considered lies therefore between,

[1] note then that, in the large network MIMO viewpoint, such terminology as "serving cells" does not make sense since all cells serve each particular UE.

- having a large number of base stations cooperating to restrict interference to low energy, at the expense of a high feedback load,
- turning the network into sub-networks of a few cooperative cells, resulting into limited but non-trivial interference at a low feedback price.

The analysis of this trade-off under realistic assumptions will provide insight into the number of cooperative base stations (i.e. the size of the *cooperative clusters*) which LTE-A can support.
As an example, [3] provides practical schemes for UE's to select the surrounding base stations to cooperate with, based on selecting only base stations that satisfy particular requirements (e.g. absolute or relative SNR requirements). The rationale is that the UE's are willing to communicate to many base stations only if they have a strong enough link (absolute or relative to the most powerful serving cell).
However, the answer to the trade-off will depend on the scheme selected in order to define clustered base stations and further discussions on this issue are needed. Given a small set of participating cells, the potential performance benefit of network MIMO using multi-cell beamforming approaches can easily demonstrated, for example as shown in [4]. [4] shows the total system throughput improvement which arises by using multiple cells under one eNB to jointly create MU-MIMO beams to certain users, while reducing the total number of simultaneously-scheduled users in each TTI. The increase in throughput for the beamformed users outweighs the reduction in throughput arising from the reduction in number of simultaneously-scheduled users.

4 Conclusion

Considering the limited gain of MIMO techniques in practical communication networks, we showed that network MIMO considerations are of relevance, especially in the case of LTE-A. The aim of this contribution is to point out the main trade-off between the gain of cooperative MIMO when N base stations are allowed to cooperate and the feedback burden that it can cause. The complexity and the uplink load are important issues that need to be considered when defining the number of cooperative base stations that LTE-A can support. More detailed analysis will be presented in future contributions.

References

[1] I.E. Telatar, "Capacity of multi-antenna Gaussian channels," Tech. Rep., ATT Bell Labs, 1995.

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[3] A. Papadogiannis, H. J. Bang, D. Gesbert and E. Hardouin, "Downlink Overhead Reduction for Multi-Cell Cooperative Processing enabled Wireless Networks", 2008.

[4] Philips, “Multi-cell co-operative beamforming: operation and performance”, 3GPP TSG RAN WG1 Meeting #55, R1-084100.