Enhanced Multi-Antenna Capabilities through Small Cell Collaboration

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This thesis shows that collaboration between base stations in small cell scenarios can lead to enhanced multiple-antenna gains. We demonstrate this for the case of Multi-User MIMO-based reassignments between adjacent small cells, from the perspectives of spectral efficiency, energy efficiency and number of spatial layers effectively utilised.

Downlink Multi-User MIMO (MU-MIMO) is a spatial multiplexing technique in which multiple transmit antennas at an evolved Node Base station (eNB) are used to simultaneously serve multiple User Equipments (UEs), each on a different spatial layer, in such a way that the interference between the beams directed at co-scheduled UEs is kept as low as possible. Due to MU-MIMO's ability to provide large spatial multiplexing gains without requiring additional antennas on the UE, and its ability to overcome rank deficiency problems (which often limit single point-to-point spatial multiplexing), MU-MIMO capabilities have been highly emphasised in recent standardisation.

In this thesis we focus on the use of MU-MIMO in coordinated LTE small cell networks. Small cells are an appealing technology to operators due to their low costs of deployment and operation, and their ability to dramatically increase the spatial reusability of limited spectrum.

Further, to allow fast flexible deployment of nodes for next-generation rollout or in cases of increased traffic demands, industry is interested in deploying architectures which perform the baseband processing of multiple small cells centrally at a single location, while the small cell transmitters take the form of simple Remote Radio Head devices. As extremely fast information exchange can be performed between co-located cooperating base stations, these architectures mean that coordination in centrally-deployed small cell networks is quickly being made feasible and cost effective.

MU-MIMO performs best when the antennas at the eNB are highly correlated, which is often the case in small cell scenarios. However, for effective operation, MU-MIMO requires the channels between the base station and different simultaneously-served UEs to be sufficiently uncorrelated (close to orthogonal) to ensure that excessive cross-layer interference is not experienced. While this cross-layer (or multi-user) interference can be suppressed at the transmitter using techniques such as Zero-Forcing Beam Forming, there is an associated cost in terms of signal power, meaning that the combined throughput of the spatial layers of multiple non-orthogonal UEs may be less than the unsuppressed throughput of a single UE transmitted to on single layer alone. In macrocell networks this problem is overcome by taking advantage of multi-user diversity through MU-MIMO scheduling. On the other hand, in small cell scenarios where the number of UEs per cell is low, sets of UEs with mutually orthogonal channels do not always exist in a given cell and the spatial multiplexing gains of MU-MIMO cannot always be realised. However, due to the high density of deployment in small cell networks, UEs are often in range of multiple small cells at once.

For this reason, we propose MU-MIMO-based reassignments of UEs between adjacent small cells, through which the channel orthogonality between UEs can be increased, along with the number of spatial layers which can be effectively utilised. We propose a number of network-wide-mechanisms which target different performance objectives, such as spectral efficiency and energy efficiency, through the use of centralised coordination between neighbouring small cells. We collectively call these mechanisms *Multi-User MIMO across Small Cells*.