Massive Notes 1.11

Key Points : Linear and Non-linear Receive Schemes; Multiantenna UEs

1. Linear and Non-linear Receive Schemes

1. M-MMSE is the **linear receive combining** scheme that maximizes the SE. The basic characteristic of linear schemes is that they treat interference as **spatially colored noise**. This is only optimal **when the interference between each pair of UEs is sufficiently small**.

2. Strong interference sources should be canceled using **non-linear receiver processing** schemes, such as **Successive Interference Cancellation (SIC)**, before the desired signals are decoded.

3. However, such schemes are rather impractical, since it leads to **high complexity**, **large memory requirements**, and **latency issues**. If we would limit ourselves to linear receiver processing schemes, how large is the performance loss?

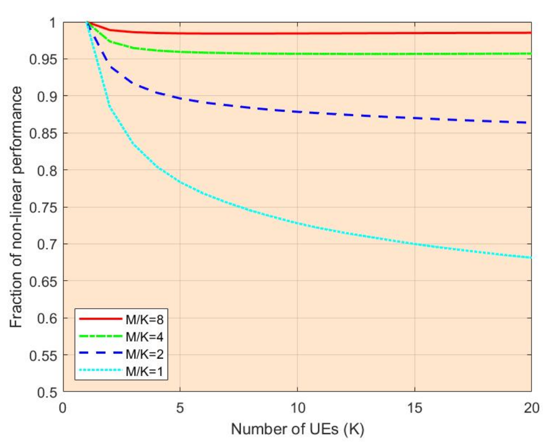

Figure 1. Ratio between the average UL sum SE achieved with M-MMSE combining and with non-linear receiver processing, as a function of the number of UEs per cell.

4. Figure 1 shows the ratio between the average UL sum SE achieved by M-MMSE combining and by SIC, where the intra-cell signals are decoded sequentially while treating inter-cell interference as noise. We only consider NLoS propagation case. Although the performance of SIC is better than M-MMSE when $M/K = 1$, **this performance difference reduces quickly as M/K increases**.

5. The interpretation is that the **favorable propagation**, achieved by having many BS antennas, makes the interference between each pair of UEs sufficiently small (i.e., the two channels are more orthogonal) to make linear receiver processing nearly optimal. When there are many active UEs, the total interference caused to a UE can indeed be large, but nevertheless, **linear processing performs well since the interference between each pair of UEs is small**.

6. In sum, UL SDMA transmission can increase **the sum SE per cell** by more than one order-of-magnitude. When $M/K \geq c$, and c is large enough, then we can provide K-fold gains in sum SE. But it is worth noting that **the SE per UE is not dramatically changed**, thus the use of **more spectrum** is still key to improving the throughput per UE. We can **use MRC to maximize the array gain**, or **use M-MMSE combining to suppress interference and maximize the SE**. Besides, SIC can only bring minor improvements when $M/K \geq c$ but it is more complicated than linear processing schemes.

2. Multiantenna UEs

7. What would happen if the UEs were also equipped with multiple antennas? The result is, **channel orthogonality is much harder to achieve in LoS propagation** since the angle between the BS and a UE in the far-field is roughly **the same** for all the antennas at the UE;

8. Hence, the benefit of sending multiple data signals cannot be exploited in propagation environments with only a dominating LoS path. The UE can, however, achieve an additional array gain proportional to N_{UE} by coherently combining the signals over N_{UE} antennas, if it knows the channel responses.

9. We can view N_{UE}-antenna UEs as N_{UE} virtual UEs that transmit N_{UE} separate signals, representing different data streams.

10. The SE is maximized when a particular number of data streams are

$$K^*_{\text{stream}} = \frac{\text{Received data streams}}{\text{Transmitted data streams}}$$

11. It is important to note that the same sum SE is achieved **when having K UEs that are equipped with $N_{\mathbf{UE}}$ antennas** and **when having $N_{\mathbf{UE}}K$ single-antenna UEs**. Hence, the distinct advantage of having multiple UE antennas occurs at low user load (END)

$$K < K^*_{\text{stream}}$$