Massive Notes 2.1

Key Points : Definition of Massive MIMO; Rule-of-Thumb for Channel Coherence

1. Definition of Massive MIMO

1. A highly spectrally efficient coverage tier in a cellular network can be characterized as follows

1) It uses SDMA to achieve a multiplexing gain by serving multiple UEs on the same time-frequency resources.

2) It has more BS antennas than UEs per cell to achieve efficient interference suppression.

3) It operates in TDD mode to limit the CSI acquisition overhead.

2. **Canonical Massive MIMO Network**: A Massive MIMO network is a multicarrier cellular network that

1) with L cells that operate according to a **synchronous TDD protocol**.

2) BS_j is equipped with $M_j \gg 1$ antennas, to achieve **channel hardening**.

3) BS_j communicates with K_j single-antenna UEs **simultaneously** with $M_j/K_j > 1$.

4) Each BS operates individually and processes its signals using **linear receiver combining** and **linear transmit precoding**.

3. It is worth noting that in particular, FDD protocol for massive MIMO is highly desirable. But it is still a great challenge.

4. **Bandwidth** B: the number of complex-valued samples that describe the signal per second (i.e., $B = 1/$the time interval between two samples).

5. **Memory Channel**: If the sample interval is short, as compared to the dispersiveness of the channel, there will be a **substantial overlap between adjacent transmitted samples** at the receiver. This memory channel is very hard to estimated or to combat inter-sample interference.

6. **Memoryless Channel**: About memory channel, a classic solution is to divide the bandwidth into many subcarriers, **each having a sufficiently narrow bandwidth so that the effective time interval between samples is much longer than the channel dispersion**. By doing so this kind of channel is memory channel. OFDM, for example, is a typical scheme.

7. **Coherence Bandwidth** B_c: describes the frequency interval over which the channel responses are approximately constant.

8. **Coherence Time** T_c: describes the time interval over which the channel responses are approximately constant.

9. **Coherence Block** τ_c: A coherence block consists of a number of subcarriers and time samples over which the channel response can be approximated as **constant** and **flat-fading**. Each coherence block contains $\tau_c = B_c T_c$ complex-valued samples.

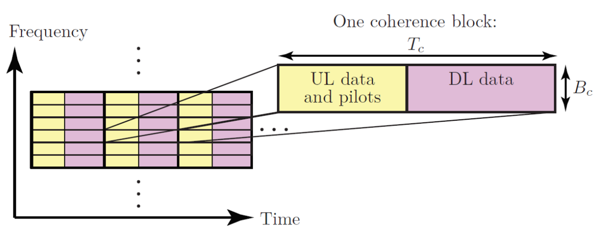
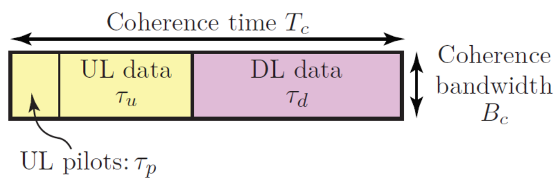
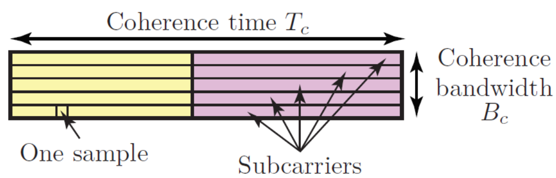


Figure 2.1: The TDD multicarrier modulation scheme of a canonical Massive MIMO network. The time-frequency plane is divided into coherence blocks in which each channel is **time-invariant** and **frequency-flat**.

10. In figure 2.1 the random channel responses in one coherence block are **statistically identical** to the ones in any other coherence block. The channel fading is described by a **stationary ergodic random process**.



(a) The samples are used for UL pilots, UL data, and DL data.



(b) The samples can belong to different subcarriers.

Figure 2.2: Each coherence block contains $\tau_c = B_c T_c$ complex-valued samples.

11. In figure 2.2, τ_p is UL pilot signals, τ_u refers to UL data signals and τ_d denotes DL data signals. Clearly we need $\tau_p + \tau_u + \tau_d = \tau_c$. Many user applications such as video streaming and web browsing mainly generate DL traffic, which means $\tau_d > \tau_u$.

12. The size of a coherence block is determined by the 1) propagation environment, 2) UE mobility, and 3) carrier frequency. Usually we decide the coherence block dimension according to the worst-case propagation scenario that the network should support.

2. Rule-of-Thumb for Channel Coherence

13. Suppose the **Doppler Shift** is $Ds = 2v/\lambda$ where v is the velocity of the UE, then the **Coherence Time** is

$$T_c = 1/(2Ds) = \lambda/(4v)$$

14. **Coherence Bandwidth** is determined by **phase differences** in the multipath propagation.

$$B_c = \frac{1}{2T_d}$$

where **Delay Spread** T_d is the time difference between the shortest and longest path.

15. The time interval between two samples is T, if

$$T \gg T_d \Rightarrow \frac{1}{T} = B \ll B_c = \frac{1}{T_c}$$

then the channel is called **flat-fading**.

16. For example, assume the carrier frequency is $f = 2\text{GHz}$, then $\lambda = 0.15\text{m}$. If $v = 37.5\text{m/s}$, so we have

$$T_c = \frac{\lambda}{4v} = \frac{0.15}{4 \times 37.5} = 0.001s = 1\text{ms}$$

$$\tau_c = B_c T_c = 200 \times 10^3 \times 1 \times 10^{-3} = 200$$