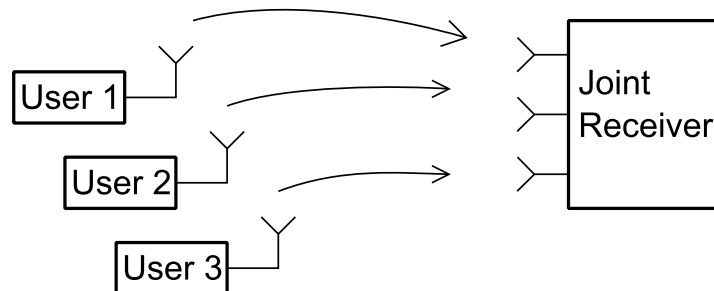
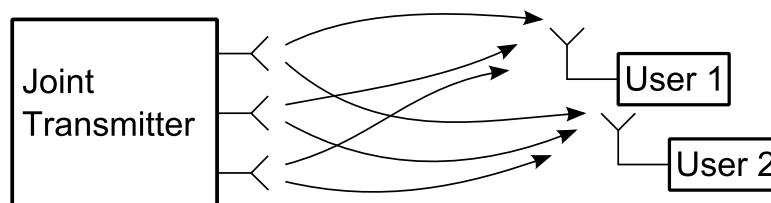


3 Multiuser MIMO

- We distinguish two cases:
 - multipoint - to - point transmission
 - point - to - multipoint transmission
- Multipoint - to - point transmission
 - typical uplink scenario in cellular systems
 - information theoretical channel model: Multiple Access Channel (MAC)



- Point - to - multipoint transmission
 - typical downlink scenario in cellular systems
 - information theoretical channel model: Broadcast Channel (BC)



- Advantage of multiuser MIMO compared to point - to - point MIMO
 - multiplexing gain can be exploited even if users have only single antenna
 - users are spatially distributed in cell → channels to different users are independent

3.1 Multiple Access Channel (MAC)

We consider two aspects:

- Detector structures
- Rate region

3.1.1 Detector structures

Channel model: Bild einfügen und diese Zeile löschen

→ general MAC: $\mathbf{y} = \sum_{k=1}^K \mathbf{H}_k \mathbf{x}_k + \mathbf{n}$

with:

- K users
- user k has $N_{T,k}$ transmit antennas
- N_R receive antennas
- $\mathbf{H}_k \in \mathbb{C}^{N_R \times N_{T,k}}$

$$\mathbf{y} = \underbrace{\begin{bmatrix} \mathbf{H}_1 & \mathbf{H}_2 & \dots & \mathbf{H}_K \end{bmatrix}}_{\mathbf{H}} \cdot \underbrace{\begin{bmatrix} \mathbf{x}_1 \\ \vdots \\ \mathbf{x}_K \end{bmatrix}}_{\mathbf{x}} + \mathbf{n}$$

Observation:

- same equivalent channel model as for a point-to-point MIMO system transmitting $N_T = \sum_{k=1}^K N_{T,k}$ independent signal streams (*Anmerkung: kein Unterschied für Empfänger, ob Signale von einem Nutzer oder von mehreren*)
- the receiver (e.g. base station) can use detection schemes as for point-to-point MIMO systems
 - linear receiver
 - DFG
 - sphere decoder

Typical problems in uplink multiuser MIMO For given receiver structure:

- calculate SNR_k for all users k based on the expressions developed in Chapter 2.4
- optimize transmit power of users, $E_k = \mathcal{E}\{\|\mathbf{x}_k\|^2\}$ for maximization of the sumrate or maximization of the minimum SNR_k (*Anmerkung: Maximierung der sumrate kann durch Maximierung des SNR des Users mit bestem Kanal erfolgen, aber: unfair anderen Usern gegenüber \Rightarrow starving*)

3.1.2 Rate region

For point-to-point links, we can decode error free, if the rate, R , meets

- SISO $R < \log_2\left(1 + \frac{\mathcal{E}_s}{\sigma_n^2}\right)$
- MIMO $R < \log_2 \underbrace{\left| \mathbf{I} + \frac{\mathcal{E}_s}{N_T \sigma_n^2} \mathbf{H} \mathbf{H}^H \right|}_{\det}$

Questions: What happens if there are multiple users?

Rate Region for Single Antenna Users and Receivers

- Gaussian channel
- $N_R = N_{T,k} = 1 \forall k$
- received signal:

$$y = \sum_{k=1}^K x_k + n$$

$$* \mathcal{E}_k = \mathcal{E}\{||x_k||^2\}$$

$$* \sigma_n^2 = \mathcal{E}\{||n||^2\}$$

Example: 2 Users Bild einfügen und diese Zeile löschen

- How should we choose R_1 and R_2 to ensure error free decoding of both signal streams?
- It is no longer sufficient to maximize a single rate. Instead we have to consider rate pairs (R_1, R_2)
- All possible rate points, that allows error free decoding, define the rate region \underline{C}
- Possible design goals of the system:
 - maximized sumrate $R_{\text{sum}} = \max_{(R_1, R_2) \in \underline{C}} R_1 + R_2$
 - maximize minimum user rate: $R_{\text{max-min}} = \max_{(R_1, R_2) \in \underline{C}} \min_{i \in \{1, 2\}} R_i$
- Rate Region of two user Gaussian MAC *Anmerkung: Einschränkungen*

$$R_1 < \log_2 \left(1 + \frac{\mathcal{E}_1}{\sigma_n^2} \right) \quad (1)$$

$$R_2 < \log_2 \left(1 + \frac{\mathcal{E}_2}{\sigma_n^2} \right) \quad (2)$$

$$R_1 + R_2 < \log_2 \left(1 + \frac{\mathcal{E}_1 + \mathcal{E}_2}{\sigma_n^2} \right) \quad (3)$$

- Interpretation:
 - (1) and (2) (= single-to-user constraint) are the “single-user bounds, i.e., the maximum rates of user 1 and 2, if the other user was not there
 - (3) can be interpreted as the maximum rate if streams of users 1 and 2 were jointly encoded. The separate encoding in the MAC cannot yield a better performance
 - Graphical representation: **Bild einfügen und diese Zeile löschen**