MIMO Skript - Wintersemester 2013
Kapitel 4

Contents

4 Distributed MIMO

- This research topic emerged ca. 10 years ago and is still a very active area of research
- Simple relaying schemes have been included in recent standards such as IEEE 802.16 (WiMAX) and LTE - Advanced
- Advantages: relay - assisted communications:
  - Relays can help to reduce the effective overall pathloss
  - Relays can also combat small - scale fading effects
  - Relays can help to realize MIMO gains with single - antenna nodes
- Challenges in relays - assisted communication:
  - Network architectures are becoming more complex
  - Synchronization across different nodes may be necessary *(Anm.: untersch. Träger-frequenzen der Relays → Offset, Fehler, etc.)*
  - Exchange of channel state information (CSI) across nodes may be required

4.1 Half - Duplex One - Way Relaying

Basic Relay Network

- Relay R assists source S in communication with destination D
- Two basic nodes of transmission (at the relay):

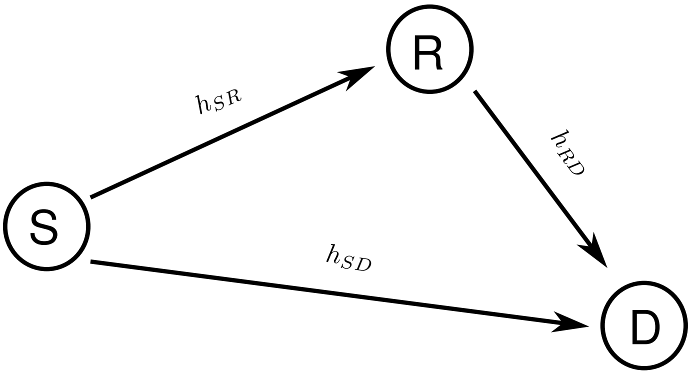

Figure 1: Basic Relay Network

Full - Duplex relaying: R can receive and transmit at the same time and in the same frequency band *(Anm.: effizient, da restliche Zeit und restliche Frequenzband von anderen genutzt werden kann)*

→ Since the TX signal power is orders of magnitude larger than the RX power, there is self - interference (at the relay)

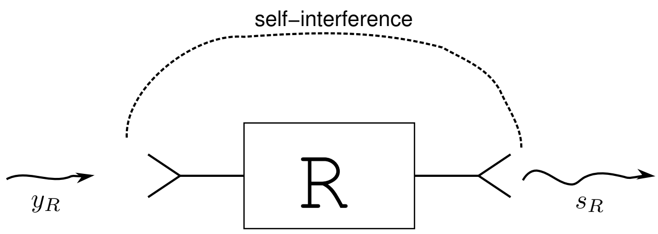

Figure 2: Relay with self-interference

→ Full - duplex relays are difficult to implement. The design of full - duplex relays is an active area of research.

→ Majority of existing literature assumes half - duplex relaying.

Half - duplex relaying: R transmits and receives in different time slots and/ or different frequency bands. Typically, a two - phase protocoll is used:

Phase 1: S transmits, R and D receive

Phase 2: R transmits, D receives, S may or may not transmit

There are different relaying strategies that differ in the processing applied at the relay. The most popular are:

- Decode - and - Forward
- Amplify - and - Forward
- (Compress - and - Forward)

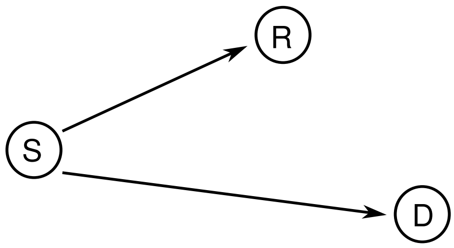

Figure 3: Half-duplex Relaying: Phase 1

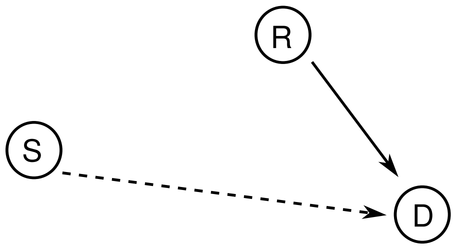

Figure 4: Half-duplex Relaying: Phase 2

4.1.1 Decode - and - Forward (DF) Relaying

In DF relaying, the relay detects and decodes the signal received from the source before encoding it and forwarding it to the destination.

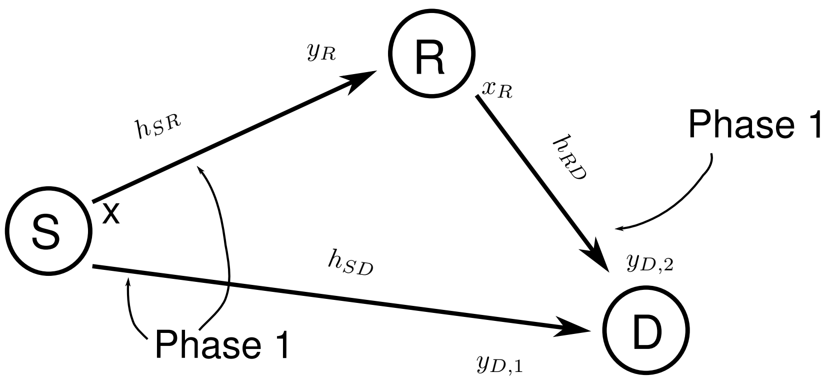

Figure 5: Decode - and - forward Relaying

Phase 1:

- R receives: $y_R = h_{SR}x + n_R$
- D receives: $y_{D1} = h_{SD}x + n_{D1}$
- with:
  - transmit signal $x, \mathcal{E}_s = \mathcal{E}\{|x|^2\}$

- AWGN n_R and n_{D1}, $\sigma_n^2 = \mathcal{E}\{|n_R|^2\} = \mathcal{E}\{|n_{D1}|^2\}$

Phase 2:

- R decodes and forwards x_R (estimate of x)
- D receives: $y_{D2} = h_{RD}x_R + n_{D2}$
  - x_R is estimate of x after decoding at R
  - $\sigma_n^2 = \mathcal{E}\{|n_{D2}|^2\}\,; \quad \mathcal{E}_R = \mathcal{E}\{|x_R|^2\}$
  - weassume: S is silent in Phase 2

- The capacity at the three node relay channel is not known!
- We provide an achievable rate under the following simplifying assumption: The direct source - relay link is not used/ exploited.
- Achievable rate without S - D link:

$$\boxed{C_{DF} = \frac{1}{2}\min\left\{\log_2\left(1 + \frac{\mathcal{E}_S|h_{SR}|^2}{\sigma_n^2}\right),\, \log_2\left(1 + \frac{\mathcal{E}_R|h_{RD}|^2}{\sigma_n^2}\right)\right\}}$$

  - factor $\frac{1}{2}$ is due to the fact that we use two time slots to transmit one packet
  - $\min\{\ldots\}$ means we are limited by the weaker link (bottle - neck)
  - If power allocation is possible, the total power $\mathcal{E} = \mathcal{E}_S + \mathcal{E}_R$ should be divided between S and R to guarantee:

$$\frac{\mathcal{E}_S|h_{SR}|^2}{\sigma_n^2} = \frac{\mathcal{E}_R|h_{RD}|^2}{\sigma_n^2},$$
$$\mathcal{E}_R = \frac{|h_{SR}|^2}{|h_{SR}|^2 + |h_{RD}|^2} \cdot \mathcal{E},$$
$$\mathcal{E}_S = \frac{|h_{RD}|^2}{|h_{SR}|^2 + |h_{RD}|^2} \cdot \mathcal{E}$$

- Outage - probability in fading:
  - We transmit with fixed rate R
  - An outage occurs, if:

$$\frac{1}{2}\log_2\Big(1 + \underbrace{\frac{\mathcal{E}_S|h_{SR}|^2}{\sigma_n^2}}_{=\gamma_{SR}}\Big) < R \quad \text{or}$$
$$\frac{1}{2}\log_2\Big(1 + \underbrace{\frac{\mathcal{E}_R|h_{RD}|^2}{\sigma_n^2}}_{=\gamma_{RD}}\Big) < R$$

$$\boxed{\gamma_{SR} < \underbrace{2^{2R} - 1}_{\gamma_T} \quad \text{or} \quad \gamma_{RD} < 2^{2R} - 1}$$