COST 289 / 6th MCM: Experimental Performance Evaluation of Multiuser Zero Forcing Relaying in Indoor Scenario

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RACOON Lab

Outline

- System model
- Zero forcing relaying
- Channel measurements
- Performance results

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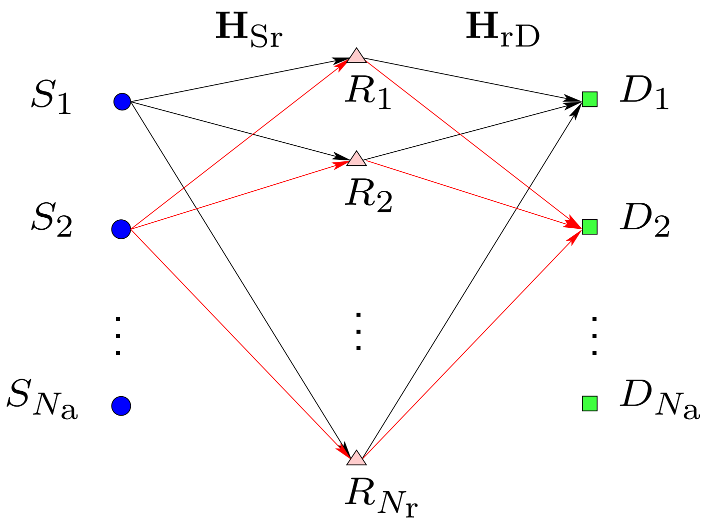
System Model

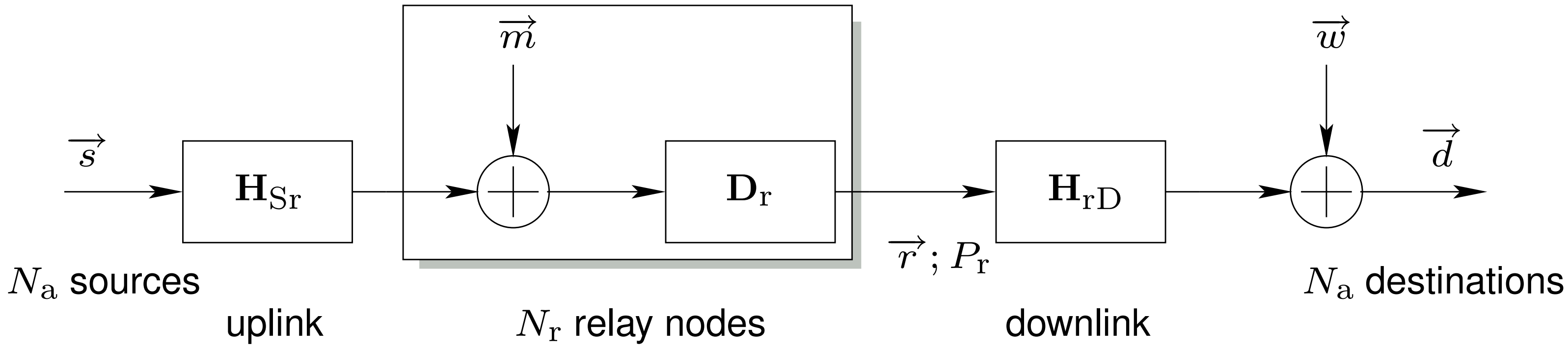


- System configuration with
  - N_{a} source - destination pairs
  - N_{r} autonomous *amplify-and-forward* relays

- S_i shall transmit to D_i without interference from other sources

- Assume: Complete channel state information at all relays
  $\rightarrow$ Multiuser Zero Forcing Relaying

System Model



- No channel knowledge at the transmitter: entries of $\overrightarrow{s}$ i.i.d. complex normal

- $\overrightarrow{m} \sim \mathcal{CN}\left(\mathbf{0}, \sigma_{\mathrm{m}}^2 \mathbf{I}_{N_{\mathrm{r}}}\right)$ and $\overrightarrow{w} \sim \mathcal{CN}\left(\mathbf{0}, \sigma_{\mathrm{w}}^2 \mathbf{I}_{N_{\mathrm{a}}}\right)$ comprise AWGN contributions at relays and destinations, respectively

- Stand-alone relays: Gain matrix $\mathbf{D}_{\mathrm{r}}$ diagonal

- *Power constraint*: No power loading at sources, sum power constraint at relays

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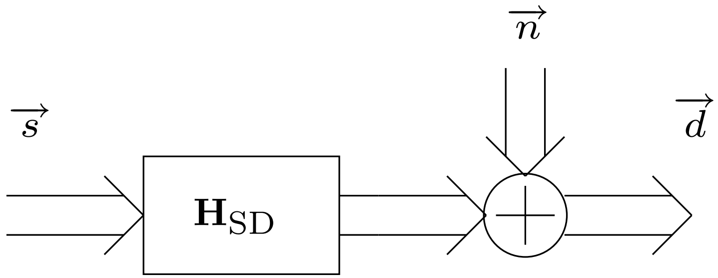
Zero Forcing Relaying



- Equivalent system model: $\overrightarrow{d} = \mathbf{H}_{\mathrm{SD}}\overrightarrow{s} + \overrightarrow{n}$ with $\mathbf{H}_{\mathrm{SD}} = \mathbf{H}_{\mathrm{rD}}\mathbf{D}_{\mathrm{r}}\mathbf{H}_{\mathrm{Sr}}$ and coloured noise

- Equivalent channel matrix:

$$\mathbf{H}_{\mathrm{SD}}[p,q] = \overrightarrow{d_{\mathrm{r}}}^{\mathrm{H}} \left(\mathbf{H}_{\mathrm{rD}}^{\mathrm{T}}[:,p] \odot \mathbf{H}_{\mathrm{Sr}}[:,q]\right)$$

  with $\mathbf{H}_{\mathrm{SD}} \in \mathbb{C}^{N_{\mathrm{a}} \times N_{\mathrm{a}}}$

- Orthogonal subchannels if $\mathbf{H}_{\mathrm{SD}}[p,q] = 0 \quad \forall\, p \neq q$

Zero Forcing Relaying

- This is fulfilled when

$$\overrightarrow{d_{\mathrm{r}}}^{\mathrm{H}} \left[\vdots, \ldots, \vdots, \mathbf{H}_{\mathrm{RD}}^{\mathrm{T}}[:,q] \odot \mathbf{H}_{\mathrm{SR}}[:,p], \vdots, \ldots, \vdots \right] \stackrel{!}{=} \mathbf{0} := \overrightarrow{u}^{\mathrm{H}}\mathbf{H}$$

- $\overrightarrow{u}$ is projection of $\overrightarrow{d_{\mathrm{r}}}$ onto nullspace of $\mathbf{H}$, where

$$\mathbf{H}[:,k] \equiv \mathbf{H}_{\mathrm{rD}}^{\mathrm{T}}[:,p] \odot \mathbf{H}_{\mathrm{Sr}}[:,q] \; \forall \, p,q \in \{1,\ldots,N_{\mathrm{a}}\} \text{ and } p \neq q$$

- Then, $\overrightarrow{u}^{\mathrm{H}}\mathbf{H} = \mathbf{0}, \; \mathbf{H} \in \mathbb{C}^{\mathbf{N_r} \times \mathbf{N_a^2} - \mathbf{N_a}}$ and thus $\mathbf{H}_{\mathrm{SD}}[p,q] = 0$ for $p \neq q$

- Minimum Relay Configuration: $N_r > N_a^2 - N_a$ because Nullspace of $\mathbf{H}$ would be empty if $N_r = N_a^2 - N_a$ and $\mathbf{H}$ has full rank.

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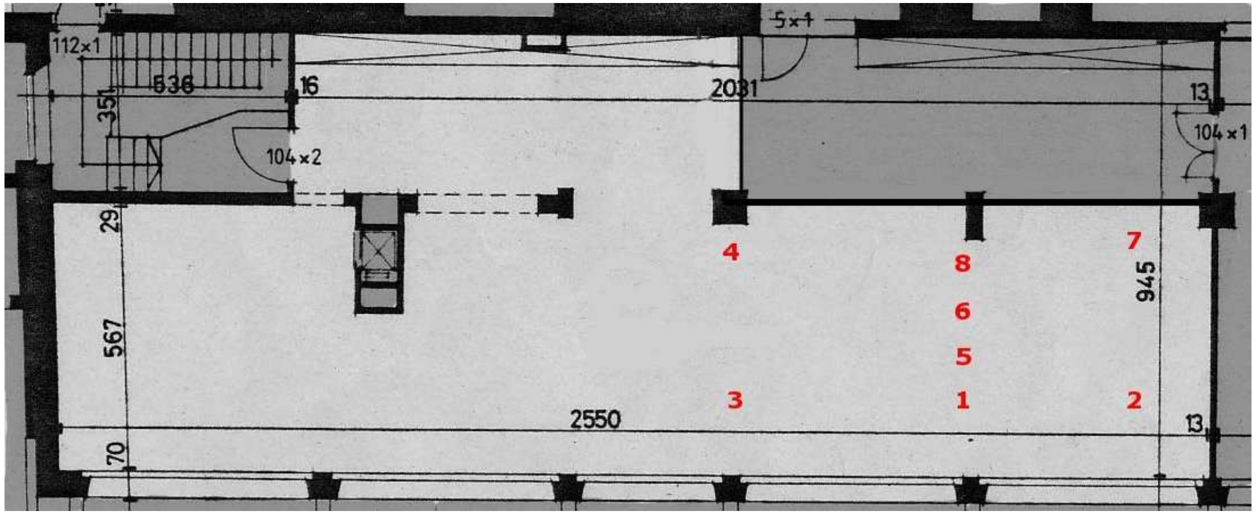
Channel measurements

- Channel measurements with RACooN Lab in ETF B104



- 2 source-destination pairs and 4 relays → 8 uplink and 8 downlink SISO channels

- Eight single antenna nodes (4 sources, 4 destinations) to measure all SISO links

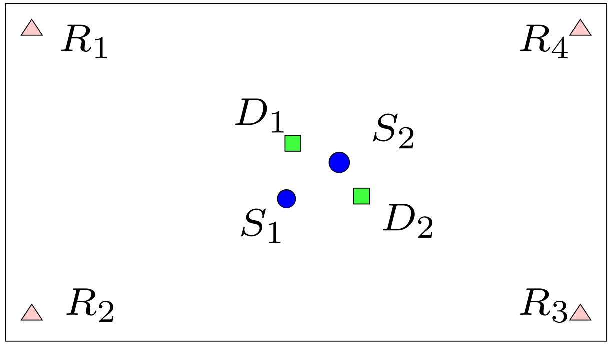
- Each node either in transmit (Tx) or receive (Rx) mode

Channel measurements

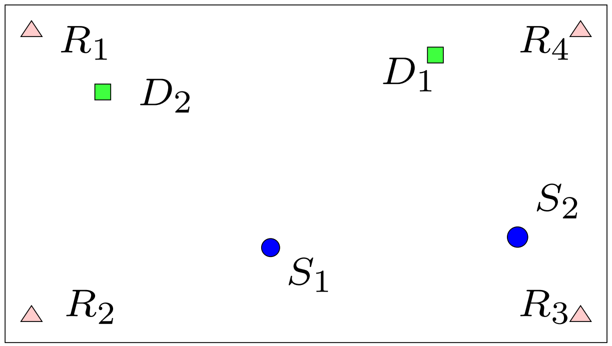
- Rubidium clock keeps synchronization (clock rate 80 MHz)
- Center frequency 5.25 GHz, bandwidth 80 MHz
- Transmit power $\approx$ 20 dBm (100mW)
- Transmit an m-sequence and correlate with received signal
  $\rightarrow$ scaled *Channel Impulse Response* (CIR))
- Channel reciprocity $\rightarrow$ measure channel from sources/destinations to all relays
- Measurement of 14 configurations

Classification of measurements:

- *Meeting room*



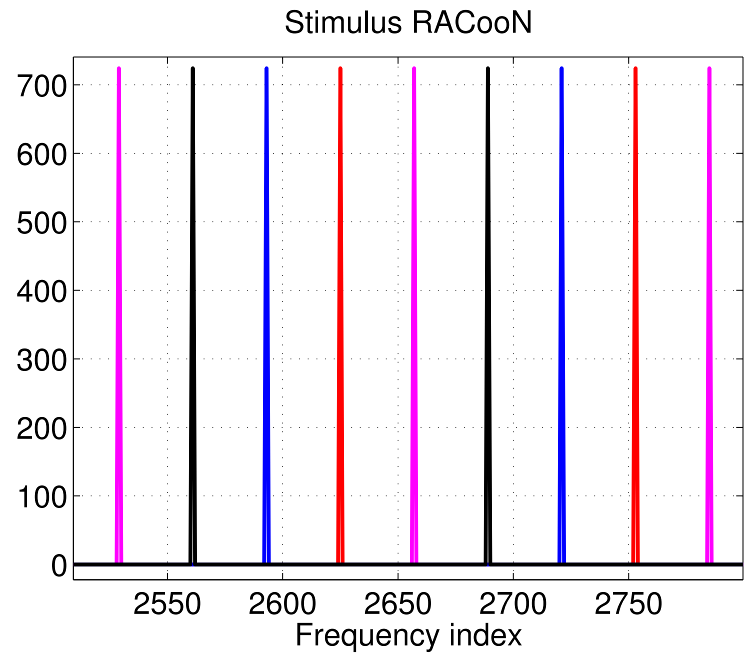
- *Open Office*



Channel measurements

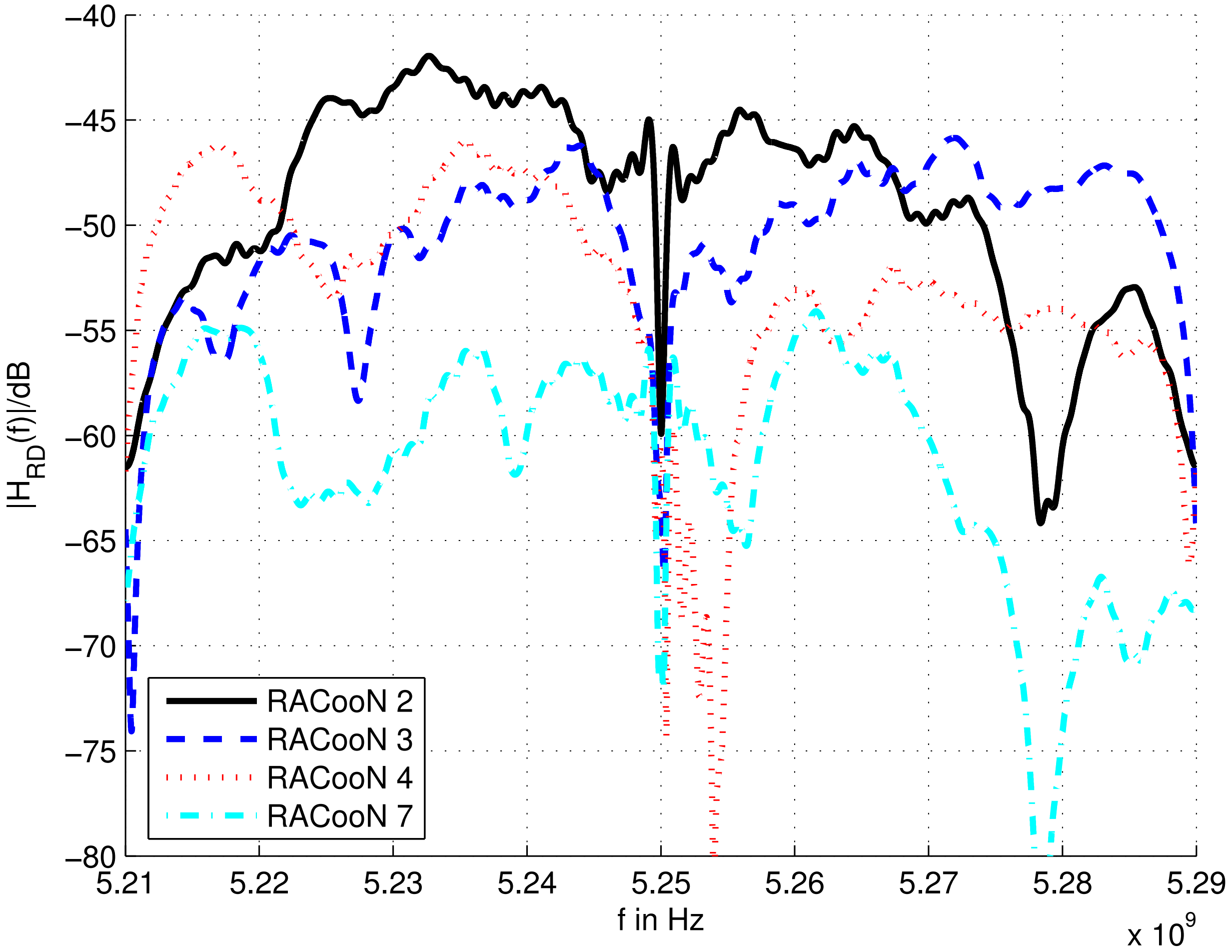
- Problem: Phase noise artificially creates uncorrelated subchannels when measuring sequentially

- Solution: Measure all channels simultaneously:
  - Transmit a repetition of m-sequences
  - Othogonalize them in frequency



Channel measurements

Transfer functions from RACooN 1 to all relays (RACooN 2, 3, 4, and 7)



Performance Results

- Determine mean channel capacity and performance gain of *Multiuser Zero Forcing Relaying*