Joint Precoder and Receiver Design for Asymmetric Two-way MIMO AF Relaying

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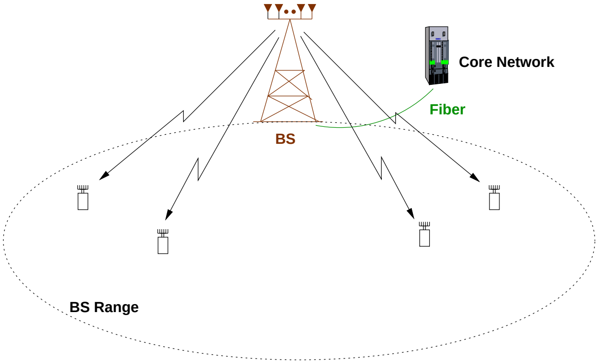
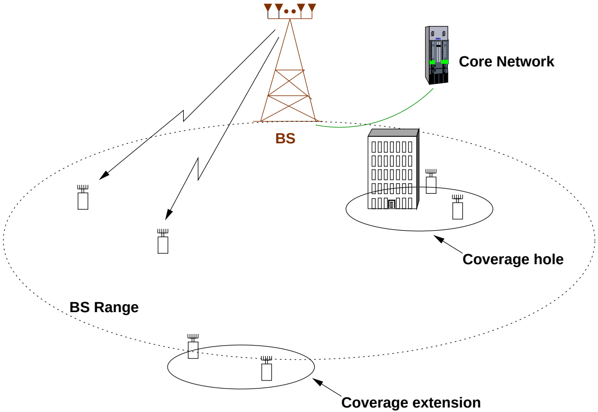
Single-hop cellular architecture



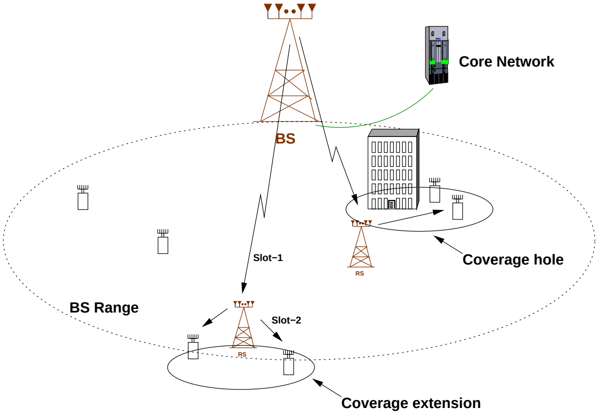
- Two links – wireless access link and wired backhaul link.
- Single-hop architecture works well if direct access links are strong.

Cellular scenarios with weak direct links



- Two examples: 1) Coverage extension; and 2) Coverage hole.
- Installing a BS for few users is costly due to core network & backhaul link.

Cellular systems with relays



- Relay is a (simplified) BS without backhaul infrastructure.
  - Relay functionality can vary from a simple repeater to a full-blown BS.

Half-duplex relaying

- Half-duplex constraint is imposed on the relay (easy to design).
  - Full-duplex technology is currently being practically evaluated.

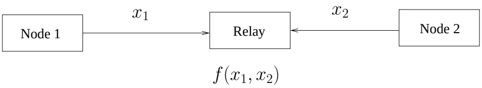
- Relay cannot transmit and receive on same spectral resource at same time.

- Two widely studied half-duplex relaying protocols:
  - One-way relay: Needs four time slots to exchange two data units.
  - Spectrally inefficient when compared with direct communication.

Figure: One-way relaying protocol.

Two-way relaying[1]

- Consists of two phases.
- MAC phase: Two source nodes simultaneously transmit to the relay.



- Broadcast phase: Relay broadcasts a function of the sum-signal.

- Both nodes can cancel back-propagating interference as both know self-data.
- Two slots are required to exchange two data units – spectrally efficient.

[1] Rankov, B and Wittneben, A, "Spectral Efficient Protocols for Half-Duplex Fading Relay Channels", IEEE J. Sel. Areas Commun, vol. 25, no. 2, pp. 375–385, 2007.

Basic assumption in two-way relaying

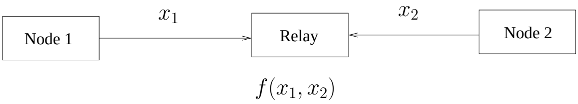
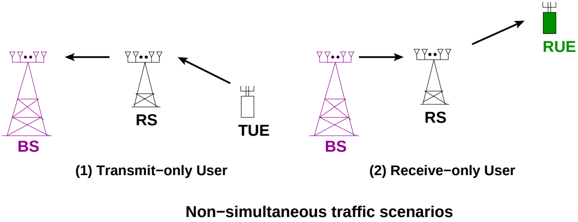


Figure: MAC phase of two-way relaying

- Two nodes want to exchange data via a relay.
- Both nodes should have data to send and receive.
- Strong assumption!

Data exchange in cellular systems

- Usually does not happen![2]



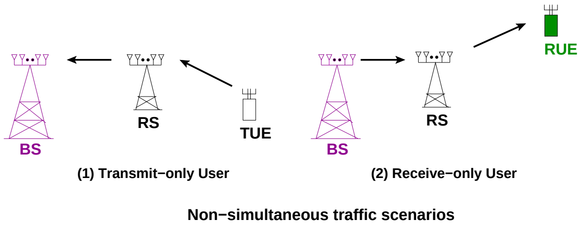
- E.g., TUE uploading a Youtube video / RUE watching a Netflix movie.
- Users either want to send or receive data.

Two way relaying cannot be used in these scenarios.

[2] Rohit Budhiraja, Karthik KS and Bhaskar Ramamurthi "Precoder design for Asymmetric Multi-user Two-way AF Relaying in Cellular Systems", ICC 2013, Hungary.

Option for BS to serve TUE and RUE

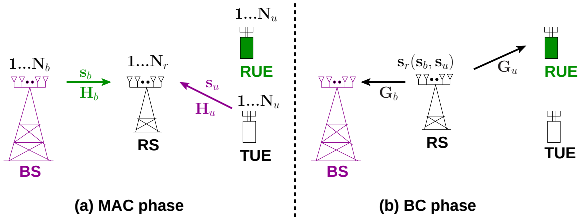
- Use one way relaying.



- BS will require 4 time slots – spectrally inefficient.

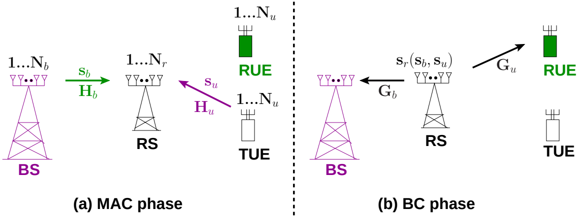
Proposed asymmetric two-way relaying (ATWR)

- MAC phase: Both BS and TUE simultaneously transmit to the relay.
- BC phase: Relay broadcasts to both BS and RUE.



- BS requires two slots to serve two users.

Back-propagating interference in ATWR



- Relay receive signal: $\mathbf{y}_r = \mathbf{H}_u \mathbf{s}_u + \mathbf{H}_b \mathbf{s}_b + \mathbf{n}_r$.
- Relay transmit signal: $\mathbf{s}_r = f(\mathbf{y}_r) = f(\mathbf{s}_u, \mathbf{s}_b)$.
- BS receive signal: $\mathbf{y}_b = \mathbf{G}_b \cdot f(\mathbf{s}_u, \mathbf{s}_b)$. BS can cancel $\mathbf{s}_b$ and detect $\mathbf{s}_u$.
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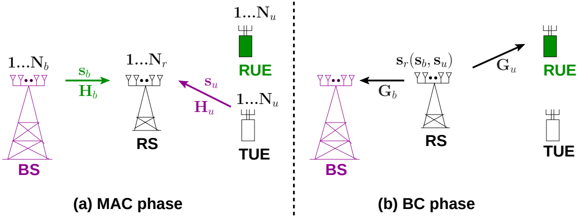

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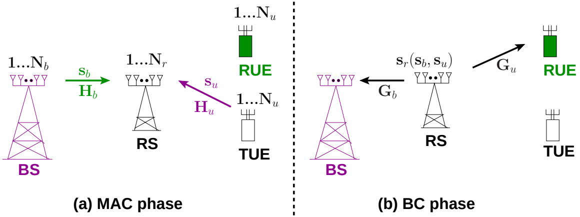

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State-of-the-art in ATWR

- Cancel BI using overhearing - assumes RUE overhears TUE in MAC phase.
  - Consider single antenna nodes.
  - Analysed sum-rate,[3] scheduling[4] and diversity multiplexing trade-off.[5]

- We do not assume overhearing and design a precoder at relay to cancel BI.
  - Consider MIMO nodes.
  - Designed relay precoder,[6] joint precoder[7] and considered multi-user scenario.[8]

[3] C. D. T. Thai et. al. Multi-Cell Multi-User Relaying Exploiting Overheard Signals, IEEE Wireless Commun. Lett., Aug. 2014.

[4] Carvalho et. al., Multi-flow scheduling for coordinated direct and relayed users in cellular systems, IEEE Trans. Commun., Feb. 2013.

[5] F. Sun et. al., Diversity-multiplexing trade-off for coordinated direct and relay schemes, IEEE Trans. Wireless Commun., 2013.

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[7] Rohit Budhiraja and Bhaskar Ramamurthi "Joint Precoder and Receiver Design for AF Non-Simultaneous Two-way MIMO Relaying", submitted after minor revision to IEEE Trans. Wireless Commun.

[8] Rohit Budhiraja and Bhaskar Ramamurthi "Multiuser Two-Way Non-Regenerative MIMO Relaying With Non-Concurrent Traffic", accepted in Trans. Vehicular Tech., 2014

Our work – two different designs

- Design a precoder at relay to cancel back-propagating interference.[9]
  - Assume relay alone has global channel knowledge.
  - Both BS and RUE use SIC to detect data; SIC can lead to errors.
  - Discussed in the first seminar.
- Joint precoder and receiver design.[10]
  - Assume all nodes have global channel knowledge.
  - Diagonalizes MIMO channels. SIC is not required.
  - Realizes beamforming gain over relay precoder.
  - Consider multi-user extension.

[9] Rohit Budhiraja, Karthik KS and Bhaskar Ramamurthi "Linear Precoders for Non-Regenerative Asymmetric Two-way Relaying in Cellular Systems", IEEE Trans. Wireless Commun., vol. 13, pp. 5002-5014, Sep. 2014

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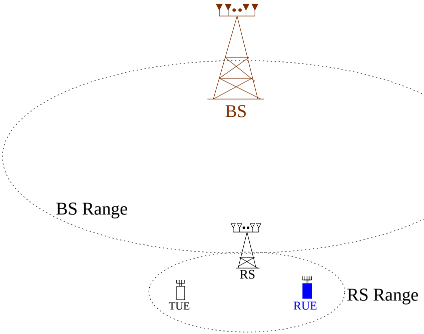
Classification of relays

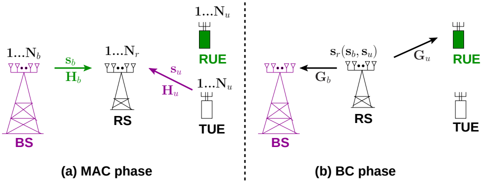
- Classified based on relay receive processing.
- Amplify-forward: Relay Tx signal: $\mathbf{x}_r = \mathbf{W}\mathbf{y}_r = \mathbf{W}\mathbf{H}\mathbf{x} + \mathbf{W}\mathbf{n}_r$.
- Amplify-forward relay amplifies noise but introduces minimal latency.
- Decode-forward: Relay decodes data. Relay Tx signal: $\mathbf{x}_r = \mathbf{P}\mathbf{x}_d$.
- Decode-forward relay removes noise but introduces considerable latency.

System model (1)

- We consider an amplify and forward relay.
- No direct links between the BS and two users.
- Users observe this channel in coverage-extension/coverage-hole scenarios.



System model (2)



- TUE and BS transmit precoded signals: $\mathbf{s}_u = \mathbf{B}_u\mathbf{x}_u$ and $\mathbf{s}_b = \mathbf{B}_b\mathbf{x}_b$.
- Relay signals:
  - MAC phase received signal: $\mathbf{y}_r = \mathbf{H}_u\mathbf{s}_u + \mathbf{H}_b\mathbf{s}_b + \mathbf{n}_r$.
  - BC phase transmit signal: $\mathbf{s}_r = \mathbf{W}\mathbf{y}_r$.
- BC phase receive signal:
  - RUE: $\mathbf{y}_u = \mathbf{G}_u\mathbf{s}_r + \mathbf{n}_u = \mathbf{G}_u\mathbf{W}\mathbf{H}_u\mathbf{s}_u + \mathbf{G}_u\mathbf{W}\mathbf{H}_b\mathbf{s}_b + \widetilde{\mathbf{n}}_u$.
  - BS: $\mathbf{y}_b = \mathbf{G}_b\mathbf{s}_r + \mathbf{n}_b = \mathbf{G}_b\mathbf{W}\mathbf{H}_u\mathbf{s}_u + \mathbf{G}_b\mathbf{W}\mathbf{H}_b\mathbf{s}_b + \widetilde{\mathbf{n}}_b$.

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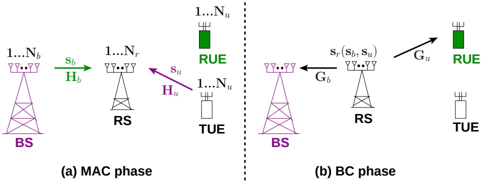

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Relay precoder design to cancel back-propagating interference

- Precoder $\mathbf{W}$ is decomposed as $\mathbf{W} = \mathbf{MDF}$.
  - $\mathbf{M} = [\mathbf{M_u}\ \mathbf{M_b}]$ and $\mathbf{F} = [\mathbf{F_u};\ \mathbf{F_b}]$ are designed to cancel RUE's BI.
  - $\mathbf{D} = \text{anti-diag}(\mathbf{D}_u,\ \mathbf{D}_b)$ is used to diagonalize MIMO channels.

- Signal received by RUE and BS after substituting $\mathbf{W} = \mathbf{MDF}$:

$$\mathbf{y} = [\mathbf{y}_u; \mathbf{y}_b] = \mathbf{GWHs} + \widetilde{\mathbf{n}} = \underbrace{\mathbf{GM}}_{\widetilde{\mathbf{G}}}\,\mathbf{D}\,\underbrace{\mathbf{FH}}_{\widetilde{\mathbf{H}}}\,\mathbf{s} + \widetilde{\mathbf{n}} = \widetilde{\mathbf{G}}\mathbf{D}\widetilde{\mathbf{H}}\mathbf{s} + \widetilde{\mathbf{n}}$$

- Block matrices: $\widetilde{\mathbf{G}} = \begin{bmatrix} \widetilde{\mathbf{G}}_u & \widetilde{\mathbf{G}}_0 \\ \widetilde{\mathbf{G}}_n & \widetilde{\mathbf{G}}_b \end{bmatrix}$ and $\widetilde{\mathbf{H}} = \begin{bmatrix} \widetilde{\mathbf{H}}_b & \widetilde{\mathbf{H}}_n \\ \widetilde{\mathbf{H}}_0 & \widetilde{\mathbf{H}}_u \end{bmatrix}$.

Design criterion for precoders $\mathbf{M}$ and $\mathbf{F}$

Lemma: To cancel RUE's BI alone, design $\mathbf{M}$ and $\mathbf{F}$ such that $\widetilde{\mathbf{G}}$ and $\widetilde{\mathbf{H}}$ are block lower- and upper-triangular matrices, respectively.

Proof: Recall $\mathbf{y} = [\mathbf{y}_u; \mathbf{y}_b] = \widetilde{\mathbf{G}}\mathbf{D}\widetilde{\mathbf{H}}\mathbf{s} + \widetilde{\mathbf{n}}$. With lower/upper-triangular $\widetilde{\mathbf{G}}/\widetilde{\mathbf{H}}$,

$$\begin{bmatrix} \mathbf{y}_u \\ \mathbf{y}_b \end{bmatrix} = \begin{bmatrix} (\widetilde{\mathbf{G}}_u\mathbf{D}_u\widetilde{\mathbf{H}}_u)\mathbf{s}_b \\ (\widetilde{\mathbf{G}}_b\mathbf{D}_b\widetilde{\mathbf{H}}_b)\mathbf{s}_u + (\widetilde{\mathbf{G}}_n\mathbf{D}_u\widetilde{\mathbf{H}}_u + \widetilde{\mathbf{G}}_b\mathbf{D}_b\widetilde{\mathbf{H}}_n)\mathbf{s}_b \end{bmatrix} + \tilde{\mathbf{n}}. \tag{1}$$

- RUE receive signal: $\mathbf{y}_u = (\widetilde{\mathbf{G}}_u\mathbf{D}_u\widetilde{\mathbf{H}}_u)\mathbf{s}_b + \tilde{\mathbf{n}}_u$.
- BS received signal (after BI cancellation): $\mathbf{y}_b = (\widetilde{\mathbf{G}}_b\mathbf{D}_b\widetilde{\mathbf{H}}_b)\mathbf{s}_u + \tilde{\mathbf{n}}_b$.
- Precoders $\mathbf{M}$ and $\mathbf{F}$ are designed based on null-space projection.
  - Designed in first seminar.

Design criterion for precoders $\mathbf{M}$ and $\mathbf{F}$

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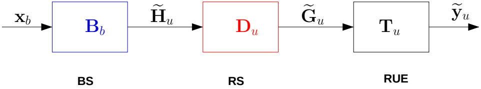
Objectives achieved with previous lemma

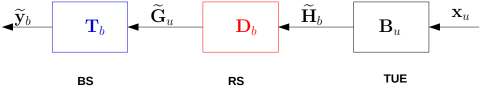
1. Cancelled RUE's BI alone.

2. Decoupled a two-way relay channel into two non-interfering one-way relay channels:

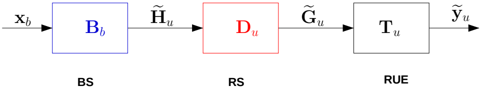
   - Downlink (BS→RS→RUE):



   - Uplink (TUE→RS→BS):



Downlink joint transceiver design



- Design $\mathbf{B}_b$, $\mathbf{D}_u$ and $\mathbf{T}_u$ to diagonalize BS→RS→RUE MIMO channel.
  - Recall, we assume all nodes have global CSI.
- Perform SVD of $\widetilde{\mathbf{H}}_u = \mathbf{U_h}\boldsymbol{\Sigma}_\mathbf{h}\mathbf{V_h}^H$ and $\widetilde{\mathbf{G}}_u = \mathbf{U_g}\boldsymbol{\Sigma}_\mathbf{g}\mathbf{V}_\mathbf{g}^H$ and choose:
  - $\mathbf{B}_b = \mathbf{U}_\mathbf{h}^H$, $\mathbf{D}_u = \mathbf{V_h}\boldsymbol{\Delta}_u\mathbf{U}_\mathbf{g}^H$, $\mathbf{T}_u = \mathbf{V_g}$.
- Diagonalized MIMO channel: $\tilde{\mathbf{y}}_u = \boldsymbol{\Sigma}_\mathbf{g}\boldsymbol{\Delta}_u\boldsymbol{\Sigma}_\mathbf{h}\mathbf{x}_b + \mathbf{T}_u\tilde{\mathbf{n}}_u$.
- Open problem – structure is optimal for one-way relay. Optimal for ATWR?

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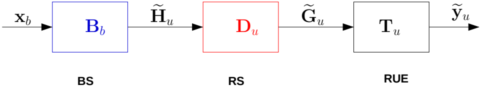

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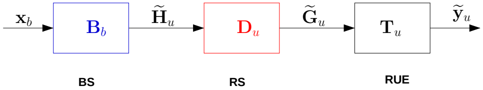

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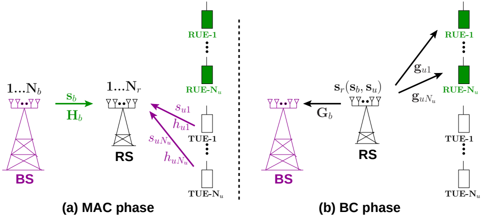
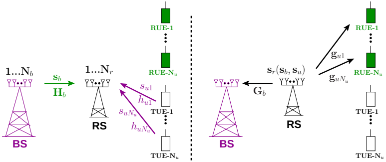
Multi-user asymmetric two-way relaying



- RUE-*n* experiences
  - Back-propagating interference from the MAC-phase transmission of TUEs.
  - Co-channel interference from data transmitted by BS to other $N_u - 1$ RUEs.

- RUEs receive interference-free signal by slightly modifying earlier design.

Multi-user asymmetric two-way relaying

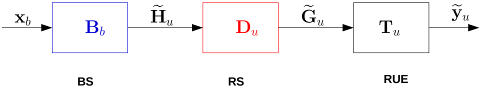


(a) MAC phase (b) BC phase

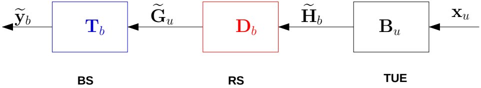
- Relay signals:
  - MAC phase: $\mathbf{y}_r = \mathbf{H}_b \mathbf{s}_b + \sum_{i=1}^{N_u} \mathbf{h}_{ui} s_{ui} + \mathbf{n}_r$; and BC phase: $\mathbf{s}_r = \mathbf{W}\mathbf{y}_r$
- RUE-n receive signal:
  - $y_{un} = \mathbf{g}_{un}^T \mathbf{s}_r = \mathbf{g}_{un}^T \mathbf{W}(\mathbf{h}_{bi} s_{bi} + \sum_{i \neq n} \underbrace{\mathbf{h}_{bi} s_{bi}}_{\text{CCI}} + \sum_{i=1}^{N_u} \underbrace{\mathbf{h}_{ui} s_{ui}}_{\text{BI}} + \tilde{n}_{un})$.
- Relay precoder $\mathbf{W}$ is designed to cancel BI.

Decoupling of channels in single-user scenario

- Relay precoder decouples two-way channel in two one-way relay channels.
  - Downlink one-way relay channel:

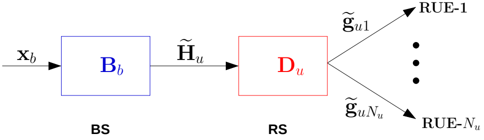


  - Uplink one-way relay channel:

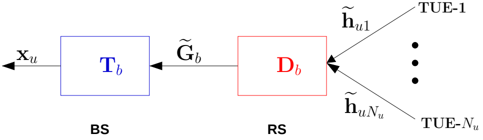


Decoupling of channels in multi-user scenario

- Relay precoder decouples two-way channel in two one-way relay channels.
  - Relay broadcast channel in downlink:

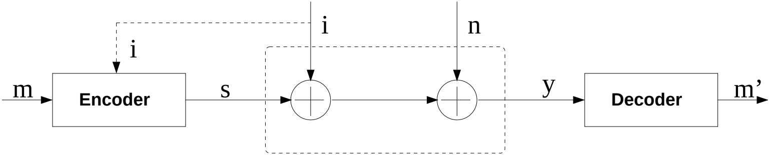


  - Relay MAC channel in uplink:



Dirty-paper-coding for point-to-point scalar channels

- Consider the following scalar interference channel $y = s + i + n$
  - i and n are independent Gaussian random variables.

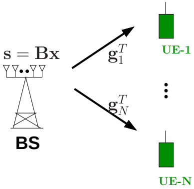


Theorem (Dirty Paper Coding)

If interference i is known non-casually at the transmitter then the capacity of the Gaussian channel is the same as if i were not present.

DPC for vector broadcast channels (ZF-DPC)

- Consider the vector broadcast channel:

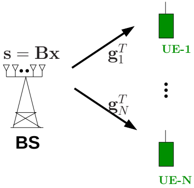


- Signal received by UE-n:
  - $y_n = \mathbf{g}_n^T \mathbf{B}\mathbf{x} + n_n = \mathbf{g}_n^T \mathbf{b}_n x_n + \sum_{j \neq n} \underbrace{\mathbf{g}_n^T \mathbf{b}_j x_j}_{\text{CCI}} + n_n$

- Stacked signals of UE-$n, \forall n$: $\mathbf{y} = \mathbf{G}\mathbf{B}\mathbf{x} + \mathbf{n}$.

DPC for vector broadcast channels (ZF-DPC)[11]

- Consider the vector broadcast channel:



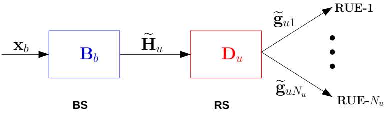
- In ZF-DPC, $\mathbf{G}$ is decomposed as $\mathbf{G} = \mathbf{LQ}$. And precoder $\mathbf{B} = \mathbf{Q}^H$.
- Equivalently $\mathbf{y} = \mathbf{GBx} + \mathbf{n} = \mathbf{Lx} + \mathbf{n}$:

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix} = \begin{bmatrix} \times & 0 & 0 & 0 \\ \times & \times & 0 & 0 \\ \times & \times & \times & 0 \\ \times & \times & \times & \times \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} + \mathbf{n}. \quad (2)$$

[11] G. Caire and S. Shamai, On the achievable throughput of a multiantenna Gaussian broadcast channel, IEEE Trans. Inf. Theory, Jul. 2003.

Downlink transceiver design

- After BI cancellation, downlink is one-way relay broadcast channel:



- Signals received by RUE-$n, \forall n$: $\mathbf{y}_u = \widetilde{\mathbf{G}}_u \mathbf{D}_u \widetilde{\mathbf{H}}_u \mathbf{B}_b \mathbf{x}_b + \tilde{\mathbf{n}}_u$.
- Design BS and RS precoders such that BS employs DPC to cancel CCI.
  - Perform SVD of $\widetilde{\mathbf{H}}_u = \mathbf{U}_\mathbf{h} \mathbf{\Sigma}_\mathbf{h} \mathbf{V}_\mathbf{h}{}^H$ and LQ dec. of $\widetilde{\mathbf{G}}_u = \mathbf{L}_\mathbf{g} \mathbf{Q}_\mathbf{g}$.
  - Choose $\mathbf{B}_b = \mathbf{U}_\mathbf{h}^H$ and $\mathbf{D}_u = \mathbf{Q}_\mathbf{g}^H \mathbf{\Delta}_u \mathbf{V}_\mathbf{h}$.
- Lower-triangular MIMO channel: $\mathbf{y}_u = \mathbf{L}_\mathbf{g} \mathbf{\Delta}_u \mathbf{\Sigma}_\mathbf{h} \mathbf{x}_b + \tilde{\mathbf{n}}_u$.

Downlink transceiver design

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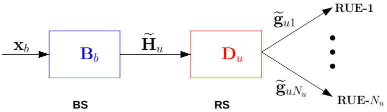

- Signals received by RUE-$n, \forall n$: $\mathbf{y}_u = \widetilde{\mathbf{G}}_u \mathbf{D}_u \widetilde{\mathbf{H}}_u \mathbf{B}_b \mathbf{x}_b + \tilde{\mathbf{n}}_u$.

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  - Choose $\mathbf{B}_b = \mathbf{U_h}^H$ and $\mathbf{D}_u = \mathbf{Q_g}^H \mathbf{\Delta}_u \mathbf{V_h}$.

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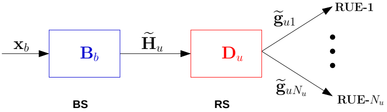
Downlink transceiver design

- After BI cancellation, downlink is one-way relay broadcast channel:



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  - Choose $\mathbf{B}_b = \mathbf{U}_\mathbf{h}^H$ and $\mathbf{D}_u = \mathbf{Q}_\mathbf{g}^H \mathbf{\Delta}_u \mathbf{V_h}$.

- Lower-triangular MIMO channel: $\mathbf{y}_u = \mathbf{L_g} \mathbf{\Delta}_u \mathbf{\Sigma_h} \mathbf{x}_b + \tilde{\mathbf{n}}_u$.

SNR experienced by BS and RUE

- SNR observed by the mth stream received by the RUE and BS:

$$\mathrm{SNR}_i^m = \frac{a_i^m \delta_{i,m}}{\sigma_r^2 (\sum_{k=1}^M b_{i,k}^m \delta_{u,k} + c_{i,k}^m \delta_{b,k}) + \sigma^2}.$$

- Here $\{a_i^m, b_{i,k}^m, c_{i,k}^m\} \geq 0$.

- Note that coefficients of power allocation variables $\delta_{u,k}$ and $\delta_{b,k}$ are positive.

- Fact will be used to prove the convexity of sum-rate optimization program.
    - $R_{\text{sum}}(\boldsymbol{\delta}) = \frac{1}{2} \sum_{m=1}^M \log\left(1 + \mathrm{SNR}_u^m(\boldsymbol{\delta})\right) + \log\left(1 + \mathrm{SNR}_b^m(\boldsymbol{\delta})\right)$

Sum-rate maximization

- Will cast sum-rate max. as a geometric program; we explain its terminology.
- A monomial is a function $f : \mathbf{R}^n_{++} :\rightarrow \mathbf{R}$ of the form

$$f(\mathbf{x}) = c x_1^{a_1} x_2^{a_2} \cdots x_n^{a_n}, \text{ where } c > 0 \text{ and } a_j \in \mathbf{R}.$$

- A positive sum of monomials is called a posynomial:

$$f(\mathbf{x}) = \sum_{k=1}^{K} c_k x_1^{a_{1k}} x_2^{a_{2k}} \cdots x_n^{a_{nk}}, \text{ where } c_k > 0$$

- Posynomials are closed under addition & multiplication, not under division.
- In a GP, the objective function and inequality constraints are posynomials.

Sum-rate maximization subject to relay power constraint

- Optimization problem can be cast as:

$$\begin{aligned} \underset{\boldsymbol{\delta}:\boldsymbol{\delta}\succeq 0}{\text{Max.}} \quad & R_{\text{sum}}(\boldsymbol{\delta}) \\ \text{s.t.} \quad & P(\boldsymbol{\delta}) \leq P_r \end{aligned} \tag{3}$$

- To cast (3) as a GP, both $R_{\text{sum}}(\boldsymbol{\delta})$ and $p_r(\boldsymbol{\delta})$ must be posynomials.

- Relay power $p_r(\boldsymbol{\delta})$ is a posynomial.[12] We show that R_{sum} is not a posynomial.

$$\begin{aligned} R_{\text{sum}}(\boldsymbol{\delta}) &= \frac{1}{2}\sum_{m=1}^{M} \log\left(1 + \text{SNR}_u^m(\boldsymbol{\delta})\right) + \log\left(1 + \text{SNR}_b^m(\boldsymbol{\delta})\right) \\ &= \frac{1}{2}\log\left[\prod_m (1 + \text{SNR}_u^m(\boldsymbol{\delta}))(1 + \text{SNR}_b^m(\boldsymbol{\delta}))\right]. \end{aligned}$$

[12] Rohit Budhiraja, Karthik KS and Bhaskar Ramamurthi "Linear Precoders for Non-Regenerative Asymmetric Two-way Relaying in Cellular Systems", IEEE Trans. Wireless Commun., vol. 13, pp. 50025014, Sep. 2014

Sum-rate maximization

- Recall SNR observed by the *m*th stream received by the RUE and BS:

$$\mathsf{SNR}_i^m = \frac{a_i^m \delta_{i,m}}{\sigma_r^2(\sum_{k=1}^{M} b_{i,k}^m \delta_{u,k} + c_{i,k}^m \delta_{b,k}) + \sigma^2}.$$

- Here $\{a_i^m, b_{i,k}^m, c_{i,k}^m\} \geq 0$. Equivalently $\mathsf{SNR}_i^m = \frac{\text{monomial}}{\text{posynomial}}$.

- Sum-rate: $R_{\text{sum}}(\boldsymbol{\delta}) = \frac{1}{2}\log\prod(1+\mathsf{SNR}_u^m(\boldsymbol{\delta}))(1+\mathsf{SNR}_b^m(\boldsymbol{\delta}))$.

- R_{sum} is a ratio of two posynomials – not a posynomial.
  - Sum-rate maximization is not a GP.

Sum-rate maximization

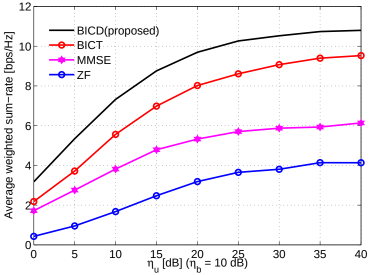
- Use high SNR approximation: $\log(1+\mathsf{SNR}) \simeq \log(\mathsf{SNR})$.

- Therefore
  - $R_{\text{sum}} \simeq \frac{1}{2}\log\left[\prod_m \mathsf{SNR}_u^m(\boldsymbol{\delta})\ \mathsf{SNR}_b^m(\boldsymbol{\delta})\right] = -\frac{1}{2}\log\left[\prod_m \mathsf{ISNR}_u^m(\boldsymbol{\delta})\ \mathsf{ISNR}_b^m(\boldsymbol{\delta})\right]$.
  - Here $\mathsf{ISNR}_u^m = 1/\mathsf{SNR}_u^m$. Note that ISNR$= \frac{\text{posynomial}}{\text{monomial}}$ is a posynomial.

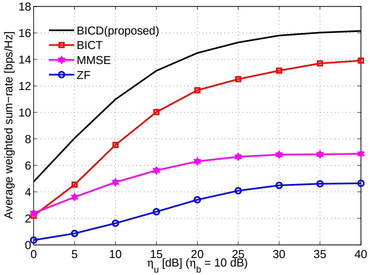
- Sum-rate maximization can now be cast as a GP:

$$\begin{aligned} \underset{\boldsymbol{\delta}\succeq 0}{\text{Min.}} \quad & \prod_m \mathsf{ISNR}_u^m(\boldsymbol{\delta})\ \mathsf{ISNR}_b^m(\boldsymbol{\delta}) \\ \text{s.t.} \quad & p_r(\boldsymbol{\delta}) \leq P_r. \end{aligned}$$

Sum-rate comparison of different precoders



(a) $N_r = 4$ and $N_u = N_b = 2$.



(b) $N_r = 8$ and $N_u = N_b = 4$.

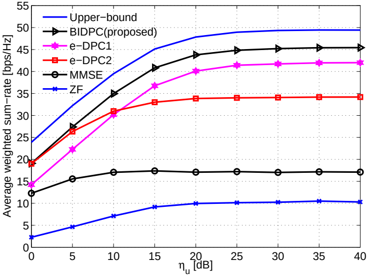
- Precoders – BICD,[13] BICT[14] and ZF/MMSE.[15]

[13] Budhiraja et. al. "Joint Precoder/Receiver Design for AF Non-Simultaneous Two-way MIMO Relaying", Trans. Wireless Commun.

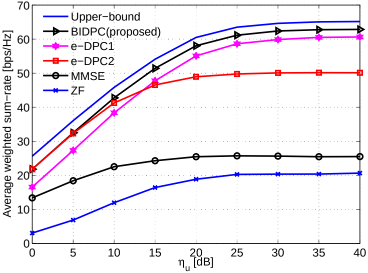
[14] Budhiraja et. al. "Linear Precoders for Non-Regenerative Asymmetric Two-way Relaying in Cellular Systems", Trans. Wireless Commun., Sep. 2014

[15] Unger et. al. "Duplex schemes in multiple antenna two-hop relaying", EURASIP J. Adv. Signal Process., vol. 2008, pp. 114, 2008.

Sum-rate comparison for multi-user ATWR



(c) With $\eta_b = 15$ dB.



(d) With $\eta_b = 20$ dB.

- Precoders – BIDPC,[16] e-DPC1,[17] e-DPC2,[18] and ZF/MMSE.[19]

[16] Budhiraja et. al. "Joint Precoder/Receiver Design for AF Non-Simultaneous Two-way MIMO Relaying", Trans. Wireless Commun.

[17] Budhiraja et. al. "Multiuser Two-Way MIMO Relaying With Non-Concurrent Traffic", Trans. Vehicular Tech., 2014

[18] Zhang et. al., "Beamforming design for multi-user two-way relaying with MIMO amplify and forward relays", ICASSP, 2011.

[19] Joung et. al. "User selection methods for multiuser two-way relay communications using space division multiple access", IEEE Trans. Wireless Commun., Jul. 2010.

Conclusions

- Considered problem of asymmetric data-flow in two-way relaying.
- Designed a novel precoder to selectively cancel back-propagating interference.
- Maximized sum-rate using geometric programming.
- Proposed precoder outperforms conventional precoders.