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Power Allocations for Nonregenerative MIMO-OFDM Relay Links

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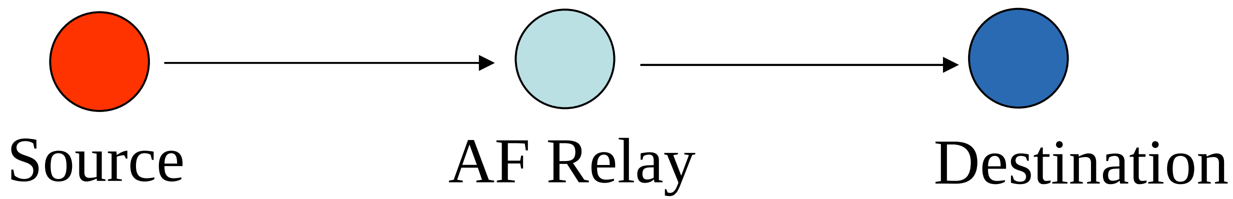
Outline

- Introduction
- System model
  - Pairing of subchannels
- Nonregenerative relaying:
  - Optimization of relay (source) power allocation with given source (relay) power allocation
  - Alternate separate optimization of source and relay power allocation
  - Joint optimization of source and relay power allocation with joint power constraint
- Simulation results
- Conclusions

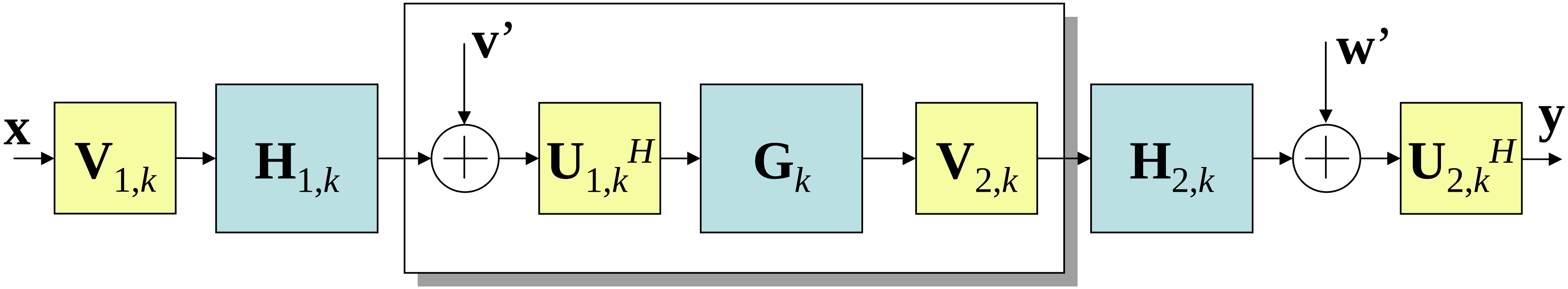
Introduction



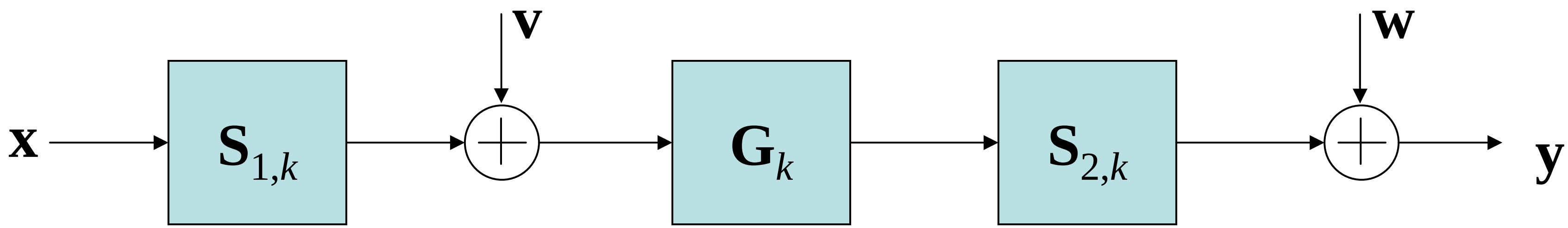
- source, relay and destination have M antennas
- nodes use OFDM with N subcarriers
- source and relay have CSI about forward channels
- 2-hop traffic pattern:
  - destination receives only in even time-slots (no direct link)

- **GOAL:**
  - optimize the transmit power allocation (PA) at source and relay jointly (or separately) with joint (or separate) power constraint such that the capacity of the link is maximized

System Model



$$\mathbf{H}_{1,k} = \mathbf{U}_{1,k}\mathbf{S}_{1,k}\mathbf{V}_{1,k}^{H} \qquad \mathbf{H}_{2,k} = \mathbf{U}_{2,k}\mathbf{S}_{2,k}\mathbf{V}_{2,k}^{H}$$



- M spatial subchannels per subcarrier
- N OFDM subcarrier

➔ overall MN orthogonal subchannels

SNR and Capacity for MIMO-OFDM Relaying

$$\rho_m = \frac{P_{s,m}\lambda_{2,m} g_m^2 \lambda_{1,m}}{\sigma_d^2 + \sigma_r^2 \lambda_{2,m} g_m^2} = \frac{P_{s,m} b_m P_{r,m} a_m}{1 + P_{s,m} b_m + P_{r,m} a_m}$$

$$\text{with } g_m^2 = \frac{P_{r,m}}{P_{s,m}\lambda_{1,m} + \sigma_r^2}, \quad a_m = \frac{\lambda_{1,m}}{\sigma_r^2} \text{ and } b_m = \frac{\lambda_{2,m}}{\sigma_d^2}$$

$$C = \frac{1}{2N}\sum_{m=1}^{MN} \log_2\left(1 + \rho_m\right)$$

- pairing of subchannels:
  - first hop and second hop eigenvalues are paired according to magnitude
  - pairing is done over space and frequency domain

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Optimization of Relay PA

$$\underset{\mathbf{p}_r}{\text{maximize}} \sum_{m=1}^{MN} \log\left(1+\frac{P_{s,m}b_m P_{r,m}a_m}{1+P_{s,m}b_m+P_{r,m}a_m}\right)$$

subject to:

$$\mathbf{p}_r \geq 0$$

$$\mathbf{1}^T\mathbf{p}_r = P_R$$

$$P_{r,m} = \frac{1}{b_m}\left[\frac{P_{s,m}a_m}{2}\left(\sqrt{1+\frac{4b_m}{P_{s,m}a_m\nu}}-1\right)-1\right]^+$$

$$\nu \in \mathbb{R}^+ \text{ such that } \sum_{k=1}^{NM} P_{r,m} = P_R$$

Optimization of Source PA

$$\underset{\mathbf{p}_s}{\text{maximize}} \sum_{m=1}^{MN} \log\left(1+\frac{P_{s,m}b_m P_{r,m}a_m}{1+P_{s,m}b_m+P_{r,m}a_m}\right)$$

subject to:

$$\mathbf{p}_s \geq 0$$

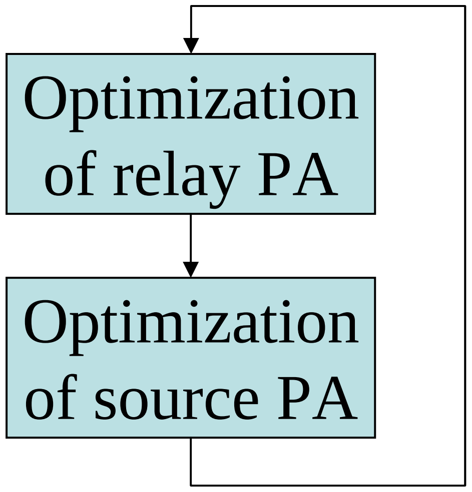
$$\mathbf{1}^T \mathbf{p}_s = P_S$$

$$P_{s,m} = \frac{1}{a_m}\left[\frac{P_{r,m}b_m}{2}\left(\sqrt{1+\frac{4a_m}{P_{r,m}b_m\nu}}-1\right)-1\right]^+$$

$$\nu \in \mathbb{R}^+ \text{ such that } \sum_{k=1}^{NM} P_{s,m} = P_S$$

Alternate Optimization of Source and Relay

- alternate repetition of separated relay and source PA optimization
  - PA of previous source (relay) PA is input to next relay (source) PA optimization
- optimization converges
- higher rates can be achieved



Joint Optimization of Source and Relay PA

$$\underset{\mathbf{p}_s,\mathbf{p}_r}{\text{maximize}} \sum_{m=1}^{MN} \log\left(1+\frac{P_{s,m}b_m P_{r,m}a_m}{1+P_{s,m}b_m+P_{r,m}a_m}\right) \approx \sum_{m=1}^{MN} \log\left(1+\frac{P_{s,m}b_m P_{r,m}a_m}{P_{s,m}b_m+P_{r,m}a_m}\right)$$

subject to:

$$\mathbf{p}_s \geq 0$$

$$\mathbf{p}_r \geq 0$$

$$\mathbf{1}^T\mathbf{p}_s + \mathbf{1}^T\mathbf{p}_r = P_\Sigma$$

$$P_m = P_{s,m} + P_{r,m} = \left[\frac{1}{\nu} - \frac{\left(\sqrt{a_m}+\sqrt{b_m}\right)}{a_m b_m}\right]^+$$

$$\nu \in \mathbb{R}^+ \text{ such that } \sum_{k=1}^{NM} P_m = P_\Sigma$$

Joint Optimization of Source and Relay PA

$$P_m = P_{s,m} + P_{r,m} = \left[\frac{1}{\nu} - \frac{\left(\sqrt{a_m} + \sqrt{b_m}\right)}{a_m b_m} \right]^+$$

$$\nu \in \mathbb{R}^+ \text{ such that } \sum_{k=1}^{NM} P_m = P_\Sigma$$

$$P_{s,m} = \frac{1}{1+\sqrt{\frac{a_m}{b_m}}} P_m$$

$$P_{r,m} = \frac{1}{1+\sqrt{\frac{b_m}{a_m}}} P_m$$

- calculation of ν by standard parallel gaussian waterfilling in at most MN steps
- relay can perform calculation with low complexity
- feedback of power levels to source

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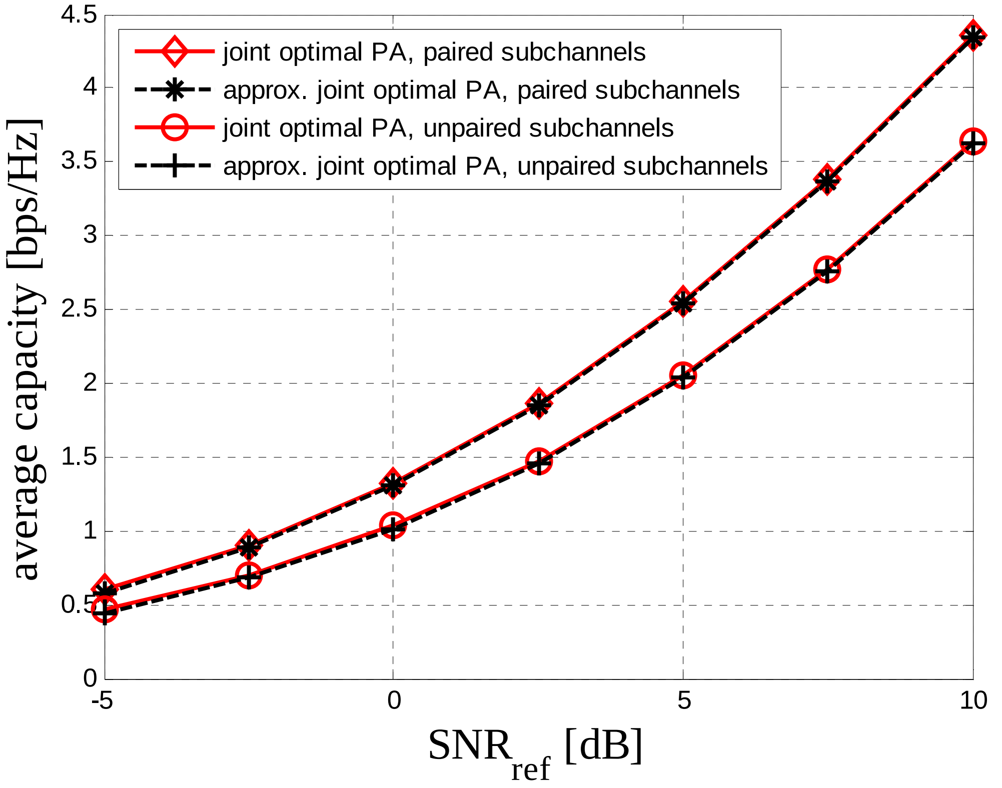
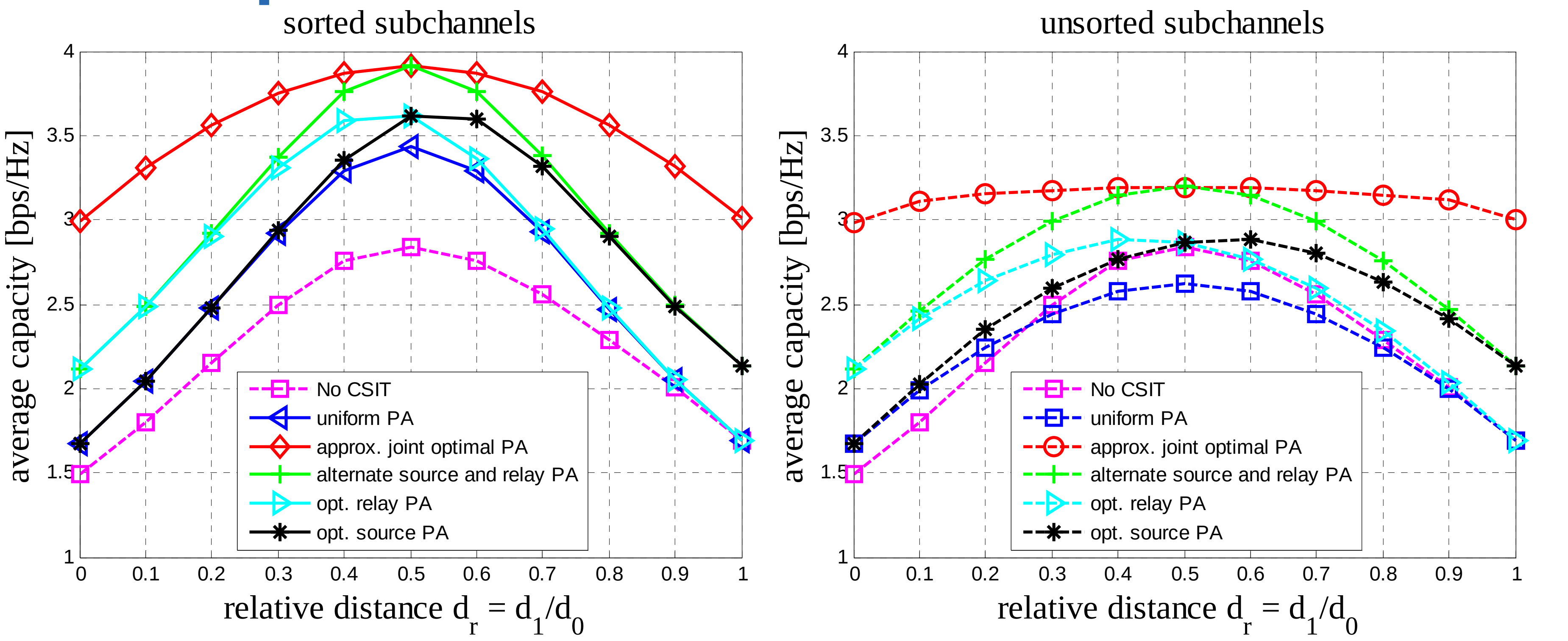
Example 1:



- M = 4 antennas
- N = 16 subcarrier
- uncorrelated Rayleigh fading
- approximation in optimization yields to a average rate which is very tight to capacity over whole SNR!

Example 2:



- subchannel pairing improves average rate
- joint optimization of source and relay PA with joint power constraint responds efficiently on relative distances

Conclusion

- PAs for nonregenerative relaying:
  - optimization of relay (source) power allocation with given source (relay) power allocation
  - alternate separate optimization of source and relay power allocation
  - joint optimization of source and relay power allocation with joint power constraint
- pairing of subchannels over space and frequency domain improves performance