Capacity Gain from Transmitter and Receiver Cooperation

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**Introduction**
- Node cooperation can be exploited to increase capacity in wireless networks.
- But not clear if transmitter cooperation or receiver cooperation offers greater benefits...
- Consider a wireless link, suppose a relay can be deployed either:
  - Near the transmitter, or
  - Near the receiver to form a cooperative cluster.
- Which provides higher capacity improvement?

**System Model**
- Discrete-time AWGN relay channel.
- Channel power gain between Tx and Rx cluster is normalized to unity, but within cluster it is denoted by $g$.
- Average network power constraint $P$.

**Operational Environments**
- We consider two models of CSI:
  - Each node has full CSI.
  - Receiver phase CSI only (remote phase information unknown).
- Also two models of power allocation:
  - Optimal power allocation: Tx has power constraint $\delta P$, and relay $(1-\delta)P$; $\delta$ 1 needs to be optimized.
  - Equal power allocation ($\delta = ?$).
- Combination results in 4 cases to consider.

**Receiver cooperation rates**
- Cut-set bound:
  \[ C_r = \max_{\alpha \in [0,1]} \min \left\{ C\left(2\alpha(1-\rho^2)\right), C\left(\alpha(1-\alpha)\rho + 2\rho \alpha \sqrt{1-\alpha \rho}\right) \right\} \]
- Achievable rate:
  - Compress-and-forward achieves the best known rate when Rx and relay are close:
    \[ R_c = C\left(\frac{2\rho \alpha \sqrt{1-\alpha \rho}}{1-\alpha \rho} + \alpha\right) \]
  - The parameters $\delta$, $\tilde{\delta}$ are to be optimized under each given operational environment.

**Transmitter cooperation rates**
- Cut-set bound:
  \[ C_t = \max_{\alpha \in [0,1]} \min \left\{ C\left(\alpha g + 1(1-\rho^2)\right), C\left(1 + 2\rho \alpha \sqrt{1-\alpha \rho}\right) \right\} \]
- Achievable rate:
  - Decode-and-forward achieves the best known rate when Tx and relay are close:
    \[ R_t = \max_{\alpha \in [0,1]} \min \left\{ C\left(\alpha g(1-\rho^2)\right), C\left(1 + 2\rho \alpha \sqrt{1-\alpha \rho}\right) \right\} \]
  - where $C(x) \triangleq \log_2(1 + xP)$.

**Case 1: Optimal power allocation with full CSI**
- Cut-set bounds are equal.
- Tx co-op rate is close to the bounds.
- Transmitter cooperation is preferable.

**Case 2: Equal power allocation with full CSI**
- Tx co-op rate is higher than the cut-set bound of Rx co-op.
- Transmitter cooperation is superior.

**Case 3: Optimal power allocation with receiver phase CSI**
- Rx co-op rate is higher than the cut-set bound of Tx co-op.
- Receiver cooperation is superior.

**Case 4: Equal power allocation with receiver phase CSI**
- Non-cooperative capacity meets the cut-set bounds of Tx and Rx co-op.
- Cooperation offers no capacity gain.

**Conclusion**
- Optimal power allocation contributes only marginal additional capacity gain.
- But full CSI is essential.
- Proper cooperation strategy is key to realize capacity gain:
  - With full CSI: Tx co-op is preferable.
  - Optimal power allocation and receiver phase CSI: Tx co-op is superior.
  - Equal power allocation and receiver phase CSI: Cooperation offers no capacity gain.
  - Implementation strategy to ease deployment of wireless ad-hoc networks:
    - Tx co-op: Homogeneous nodes are deployed, but synchronous-carrier is necessary.
    - Rx co-op: Asynchronous-carrier is used, but optimal power allocation is required.