Robust Transmit Strategies for Bidirectional Relaying

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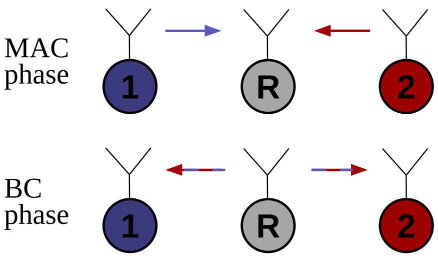
Bidirectional Relaying

- Growing interest in relaying protocols since they realize range extension by multi-hop communication
- We consider a three-node network where a **half-duplex** relay node establishes a bidirectional communication between two other nodes using a **spectrally efficient two-phase decode-and-forward protocol**



- In the first phase, the multiple access phase (MAC), both nodes transmit their messages to the relay node
- In the succeeding bidirectional broadcast phase (BC) the relay broadcasts an **optimal re-encoded message** back to the two nodes [1]

Modeling Channel Uncertainty

- Perfect knowledge about the channel state, especially on the transmitter side, is unrealistic due to the nature of the wireless channel
- Assume that the nodes merely know that the **channel belongs to a known set of channels**. This is known as **compound channel** [2]

  ⟶ **Universal strategy** is needed which works for all channels in the set simultaenously to guarantee reliable communication
- MAC phase is well-understood so that we concentrate on the bidirectional broadcast phase

Imperfect Channel Knowledge

- Transmitter and receivers merely know the set of channels and not the exact channel realization

  ⟶ They use **universal encoder and decoders** which work for all channels in the set simultaneously
- The resulting compound capacity region is given by a maxmin formulation [3]

$$co([R_{R1},R_{R2}]: R_{R1} \le \min_{t\in T} I_t(X;Y_1|U), R_{R2} \le \min_{t\in T} I_t(X;Y_2|U))$$

Channel Knowledge at Receivers

- Even if the receivers do not know the channel, it can be estimated with arbitrary accuracy by the receivers
- For sufficiently large block length the part „wasted“ for the estimation is negligible

  ⟶ **Already available channel knowledge at the receivers do not lead to a gain in capacity region**

Channel Knowledge at Transmitter

- The transmitter knows the channel realization

  ⟶ **Encoder can be adapted** to the specific channel realization, the decoders are still universal
- The resulting compound capacity region is the intersection of the rate regions of all channel realizations given by a minmax formulation [3]

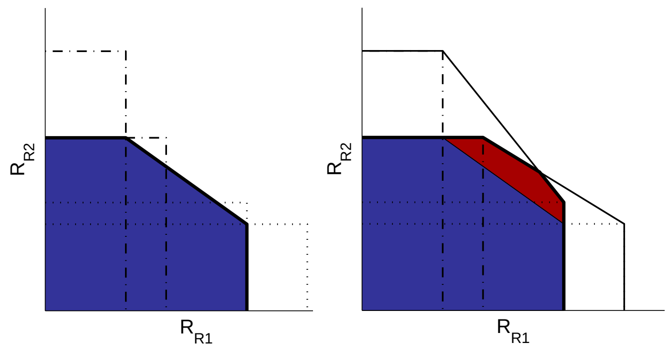
$$\bigcap_{t\in T} co([R_{R1},R_{R2}]: R_{R1} \le I_t(X;Y_1|U), R_{R2} \le I_t(X;Y_2|U))$$

  ⟶ **Channel knowledge at the transmitter can advantageously be used to enlarge the capacity region**

Game Against Nature

- Analyze the problem of reliable communication under channel uncertainty from a **game-theoretic perspective**
- Apply the **game against nature framework** [4] and assume that the nodes and the nature play a **two-player zero-sum game**, where the player wants to maximize the transmission rates, while nature wants to minimize them
- Possible transmit strategies corresponds to actions for the player, and possible channel realizations to actions for the nature

  ⟶ The concept of **security strategies** for the player and the nature immediately leads to the compound capacity regions with and without channel knowledge at the transmitter



Compound capacity region of the bidirectional broadcast phase. The figure on the left shows the case with imperfect channel knowledge, the figure on the right the case with channel knowledge at the transmitter.

References

[1] T. J. Oechtering, C. Schnurr, I. Bjelakovic, and H. Boche, „Broadcast Capacity Region of Two-Phase Bidirectional Relaying,“ *IEEE Trans. Inf. Theory*, vol. 54, no. 1, pp. 454-458, Jan. 2008.

[2] D. Blackwell, L. Breiman, and A. J. Thomasian, „The Capacity of a Class of Channels,“ *Ann. Math. Stat.*, vol. 30, no. 4, pp. 1229-1241, 1959.

[3] R. F. Wyrembelski, I. Bjelakovic, T. J. Oechtering, and H. Boche, „On the Capacity of Bidirectional Broadcast Channels Under Channel Uncertainty,“ *Proc. IEEE Int. Conf. on Commun.*, 2009.

[4] J. Milnor, „Games Against Nature,“ *the RAND corporation*, pp. 49-59, 1951.

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