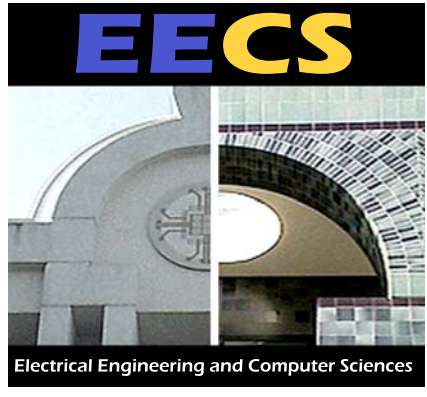


# Interference Mitigation through Limited Receiver Cooperation

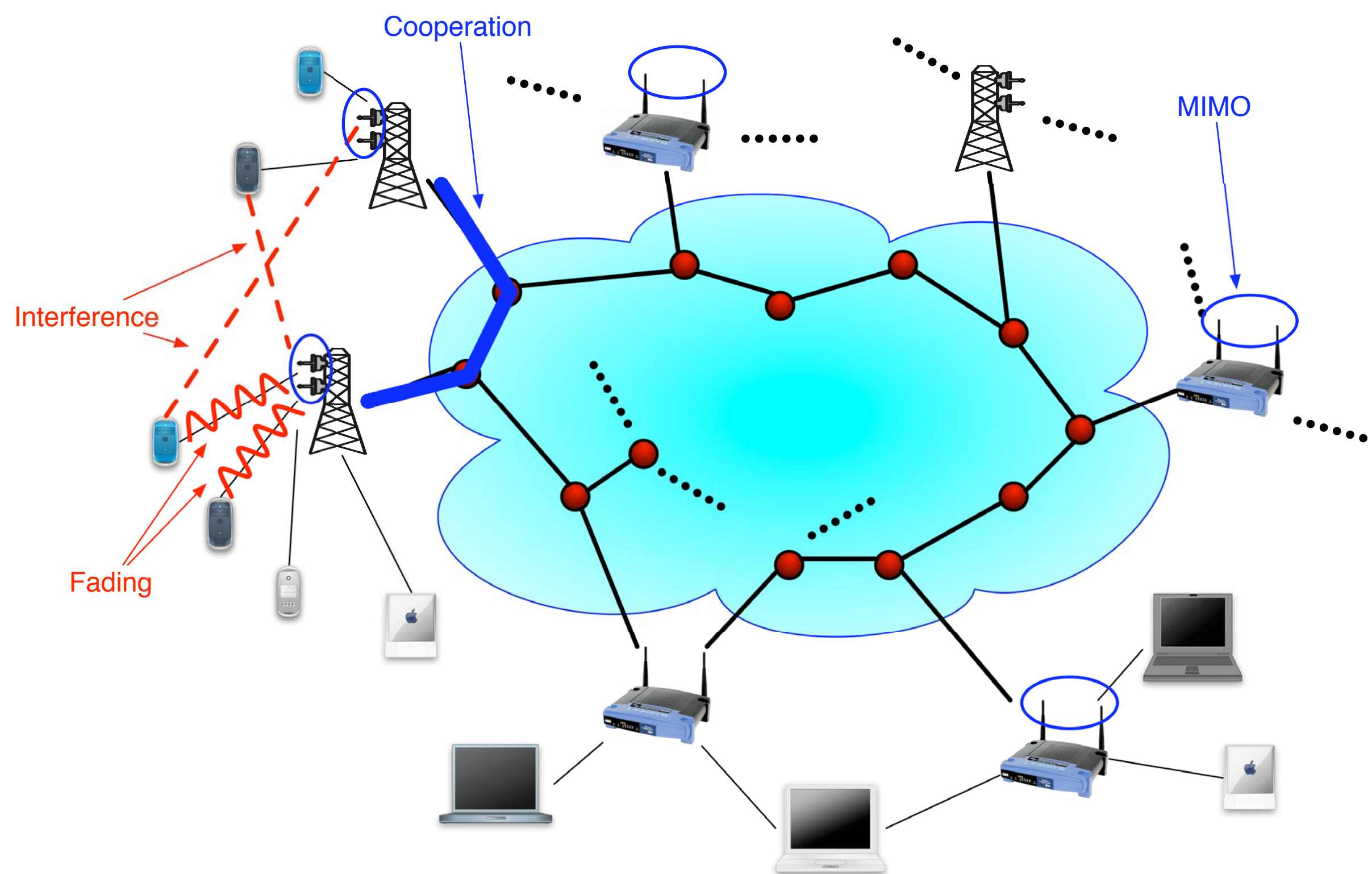


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## Motivation

Challenges in wireless networks:  
**Fading and Interference**

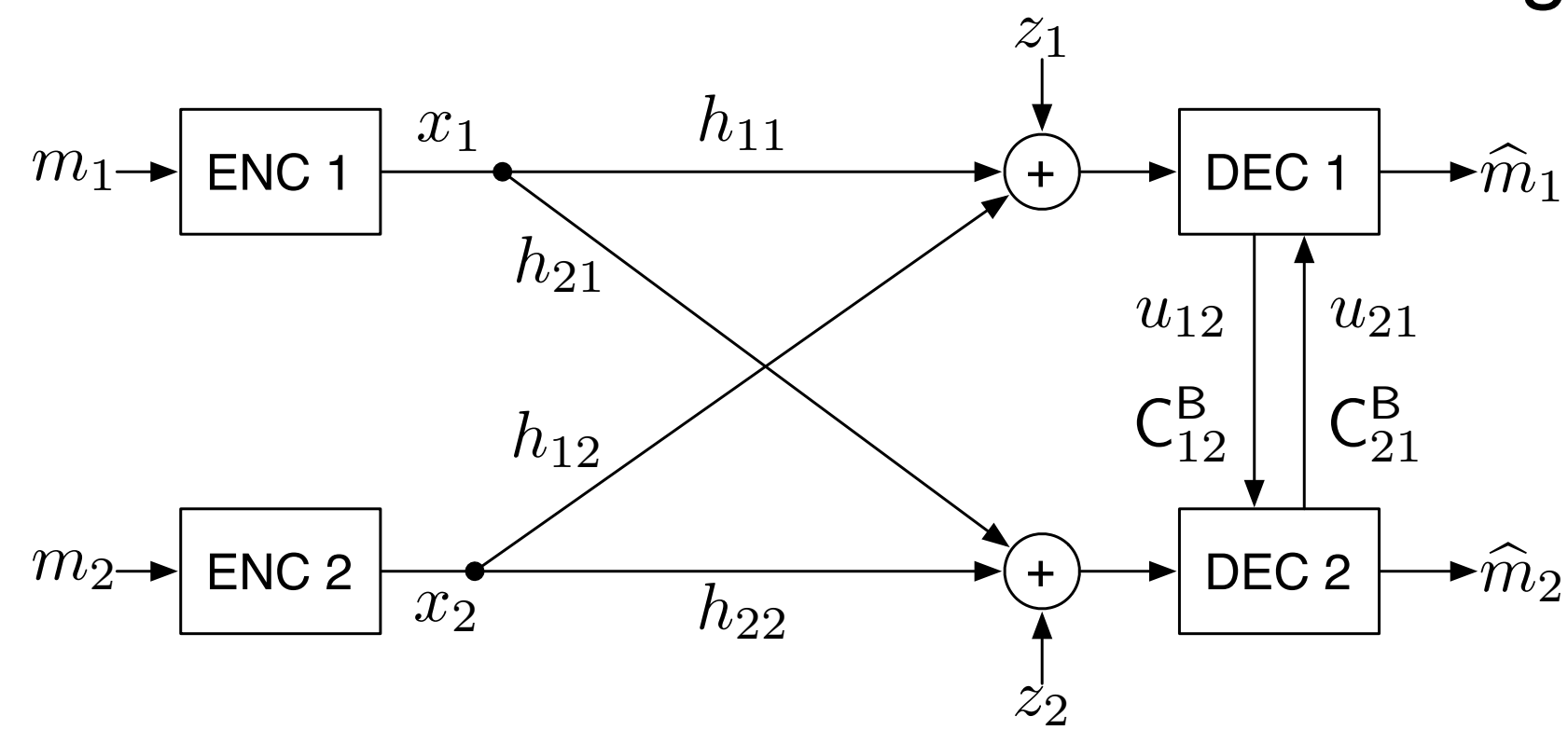


**Cooperation:** key to breaking interference barrier

How much interference can limited cooperation mitigate?

## Problem Formulation

Gaussian interference channel with conferencing decoders



$$\frac{1}{N} \sum_{n=1}^N \mathbb{E} \left[ |x_i[n]|^2 \right] \leq 1, \quad z_i[n] \stackrel{\text{iid}}{\sim} \mathcal{CN}(0, 1), \quad i = 1, 2,$$

$$\text{SNR}_i := |h_{ii}|^2, \quad \text{INR}_i := |h_{ij}|^2, \quad i, j = 1, 2, \quad i \neq j.$$

## Main Results

**Theorem:** Approximate capacity to within 2 bits [Wang and Tse '09]

$$\mathcal{R}_{\text{TwoRound}} \subseteq \mathcal{C} \subseteq \overline{\mathcal{C}} \subseteq \mathcal{R}_{\text{TwoRound}} \oplus \{(\tau, \tau)\}, \quad \text{where } \tau = 2\text{bits}.$$

**Lemma:** Outer Bounds [Wang and Tse '09]

$\mathcal{C} \subseteq \overline{\mathcal{C}}$ , where  $\overline{\mathcal{C}}$  consists of nonnegative rate tuples  $(R_1, R_2)$  satisfying: for  $(i, j) = (1, 2)$  or  $(2, 1)$ ,

$$R_i \leq \log(1 + \text{SNR}_i) + \min \left\{ C_{ji}^B, \log \left( 1 + \frac{\text{INR}_j}{1 + \text{SNR}_i} \right) \right\}$$

$$R_1 + R_2 \leq \log \left( 1 + \text{INR}_1 + \frac{\text{SNR}_1}{1 + \text{INR}_2} \right) + \log \left( 1 + \text{INR}_2 + \frac{\text{SNR}_2}{1 + \text{INR}_1} \right) + C_{21}^B + C_{12}^B$$

$$R_1 + R_2 \leq \log(1 + \text{SNR}_i + \text{INR}_i) + \log \left( 1 + \frac{\text{SNR}_j}{1 + \text{INR}_i} \right) + C_{ji}^B$$

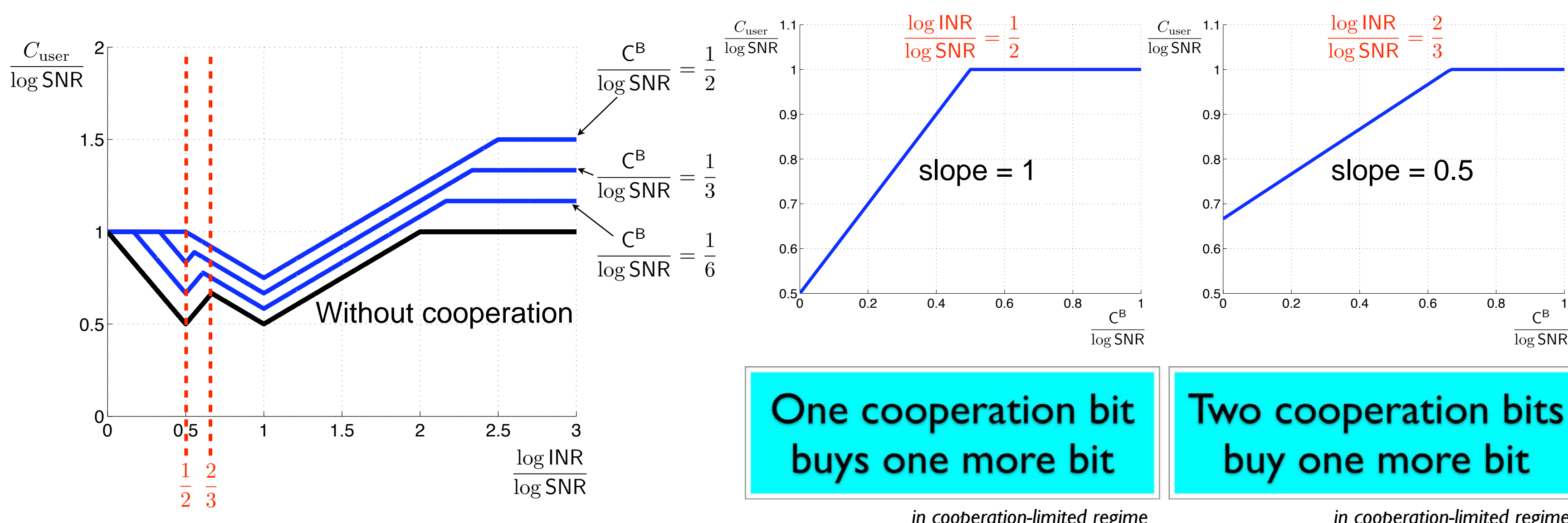
$$R_1 + R_2 \leq \log(1 + \text{SNR}_1 + \text{SNR}_2 + \text{INR}_1 + \text{INR}_2 + |h_{11}h_{22} - h_{12}h_{21}|^2)$$

$$2R_i + R_j \leq \log \left( 1 + \text{INR}_j + \frac{\text{SNR}_j}{1 + \text{INR}_i} \right) + \log \left( 1 + \frac{\text{SNR}_i}{1 + \text{INR}_j} \right) + \log(1 + \text{SNR}_i + \text{INR}_i) + C_{21}^B + C_{12}^B$$

$$2R_i + R_j \leq \log \left( 1 + \frac{\text{SNR}_j}{1 + \text{INR}_i} + \text{INR}_j + \text{SNR}_i + \frac{\text{INR}_i}{1 + \text{INR}_i} + \frac{|h_{11}h_{22} - h_{12}h_{21}|^2}{1 + \text{INR}_i} \right) + \log(1 + \text{SNR}_i + \text{INR}_i) + C_{ji}^B.$$

Cooperation-limited behavior at interference-limited regime:

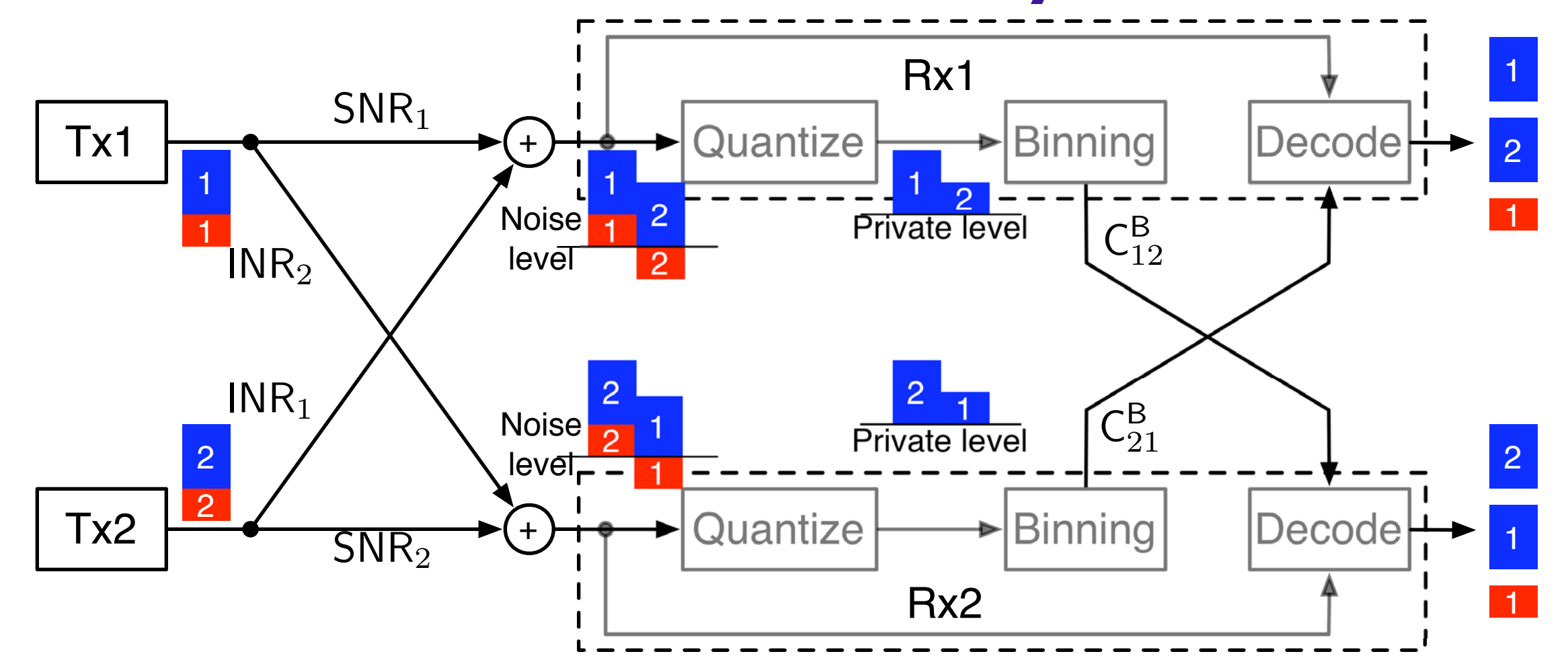
Generalized degrees of freedom



One cooperation bit  
buys one more bit

Two cooperation bits  
buy one more bit

## Achievability



- Superposition Coding:** private-common split facilitates partial interference cancellation [Han and Kobayashi '81] [Etkin et al. '08]

$$\text{INR}_{i,\text{private}} \leq 1 \Rightarrow \text{SNR}_{i,\text{private}} = \begin{cases} \min \left\{ \text{SNR}_i, \frac{\text{SNR}_i}{\text{INR}_j} \right\}, & \text{if } \text{SNR}_i > \text{INR}_j \\ 0, & \text{otherwise} \end{cases}$$

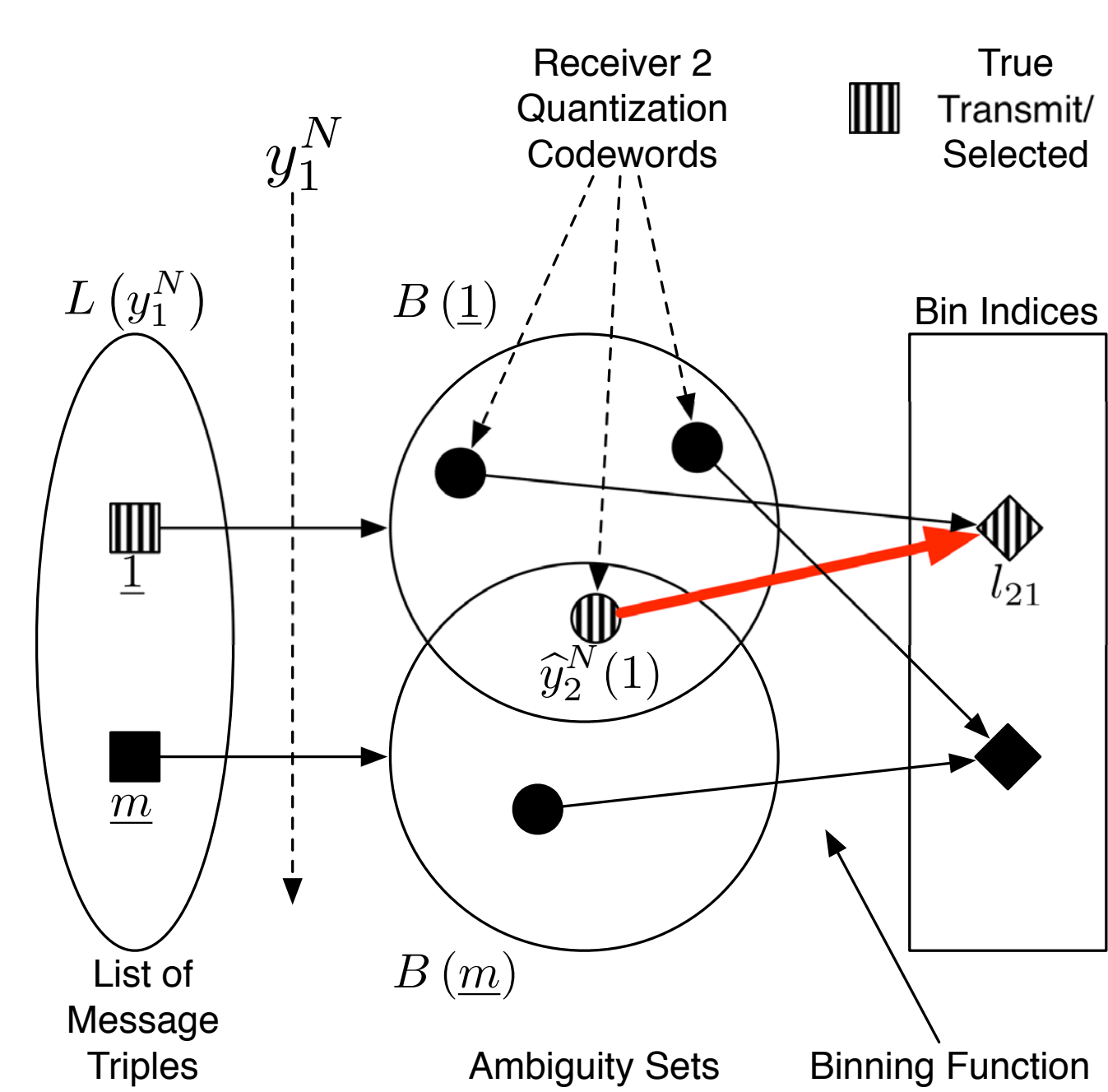
- Quantize-binning:** quantize at the maximum of private signal level and noise level

$$\Delta_{i,\text{quantize}} = \max \{ \text{SNR}_{i,\text{private}}, 1 \}$$

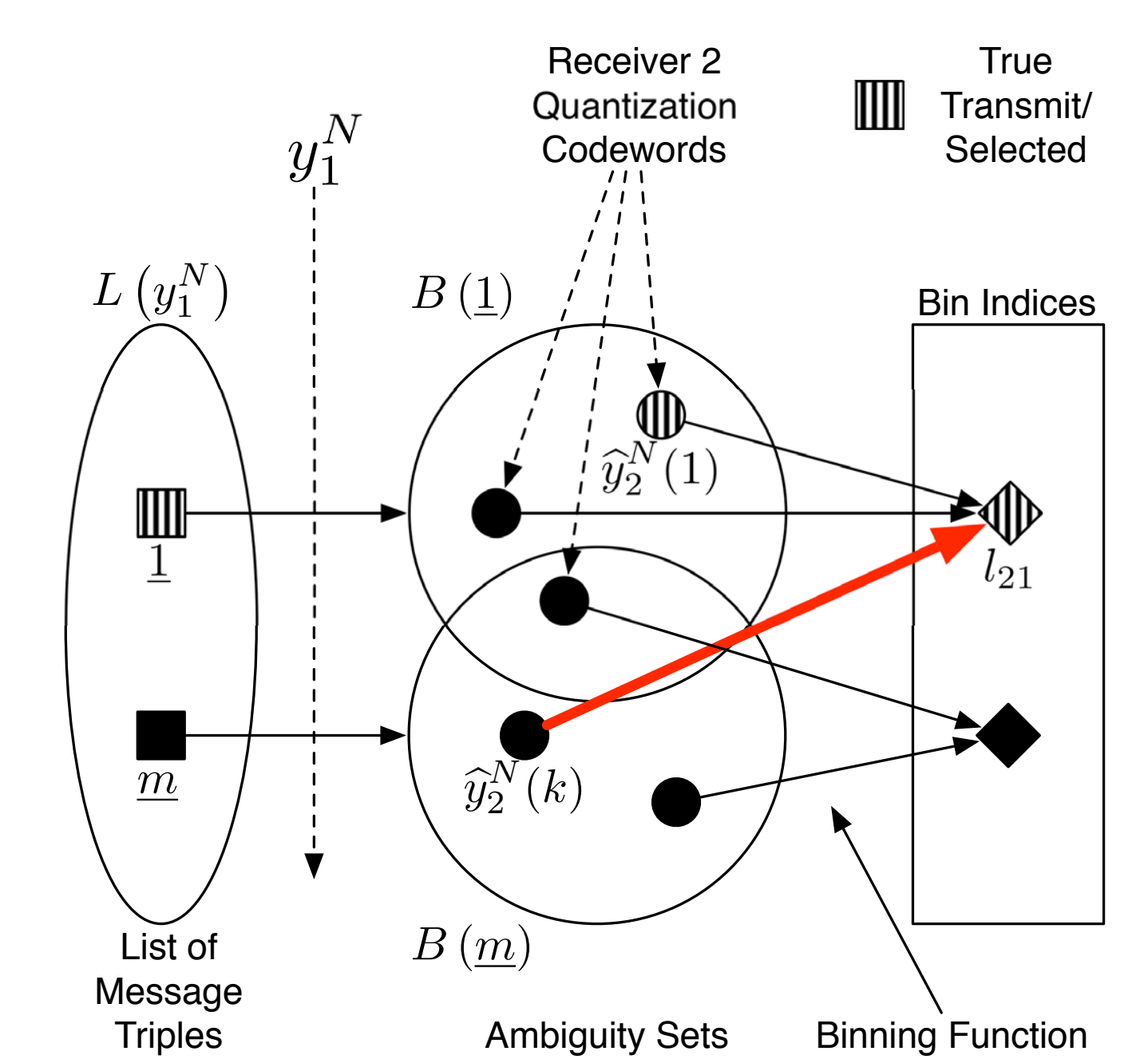
- Decoding:**

- Construct a *list* of message triples (both users' common messages and its own private message), jointly typical with its received signal from the transmitter-receiver link
- For each message triple in this list, constructs an *ambiguity set* of quantization codewords, each element of which is jointly typical with the codeword triple and the received signal
- Searches through all ambiguity sets and finds the one that contains a quantization codeword with the same bin index it received

Typical error event 1



Typical error event 2



$$R_{1p} \leq I(x_1; y_1 | x_{1c}, x_{2c}) + (C_{21}^B - \xi_1)^+$$

$$R_{2c} + R_{1p} \leq I(x_{2c}, x_1; y_1 | x_{1c}) + (C_{21}^B - \xi_1)^+$$

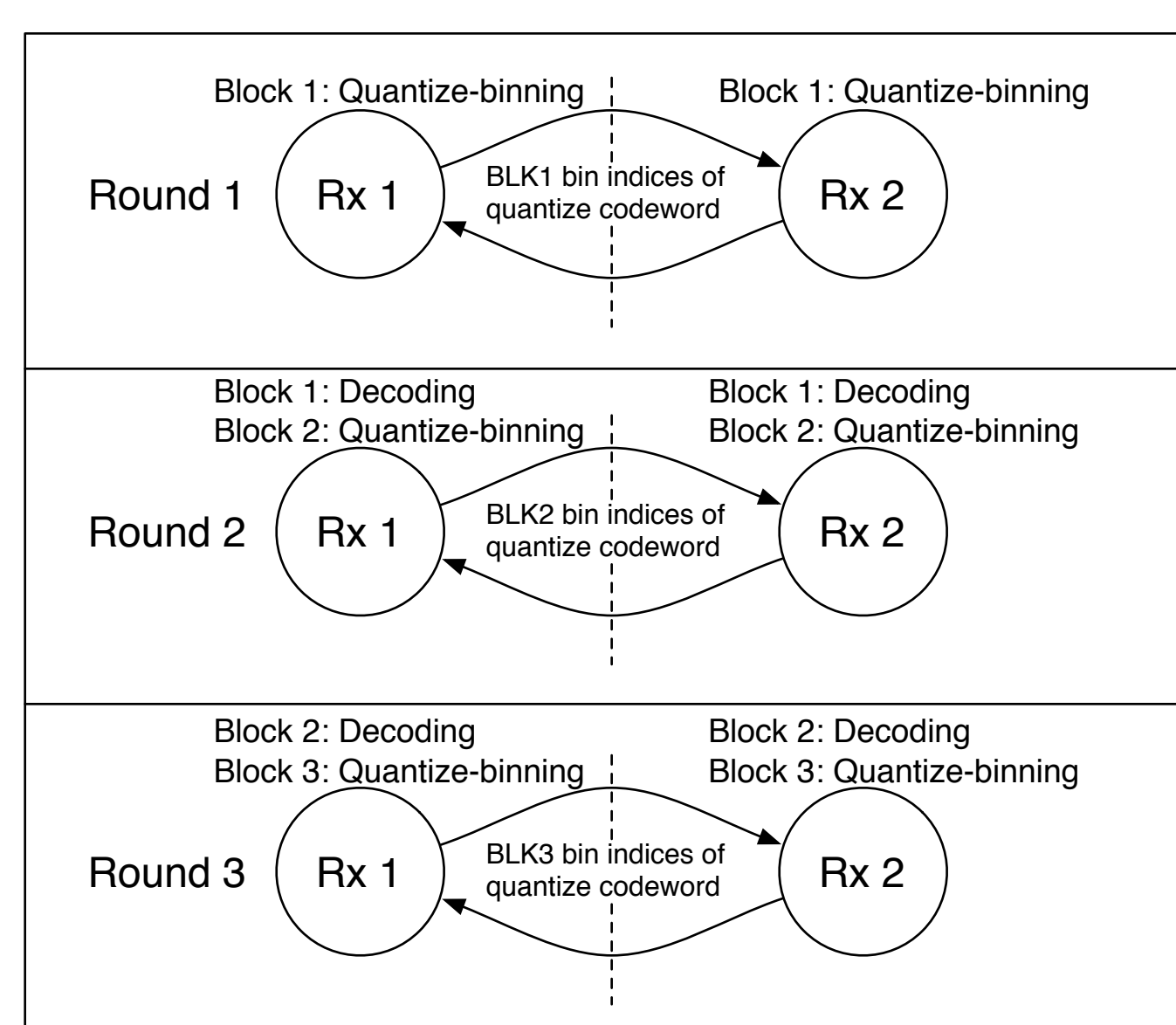
$$R_{1c} + R_{1p} \leq I(x_1; y_1 | x_{2c}) + (C_{21}^B - \xi_1)^+$$

$$R_{1c} + R_{2c} + R_{1p} \leq I(x_1, x_{2c}; y_1) + (C_{21}^B - \xi_1)^+,$$

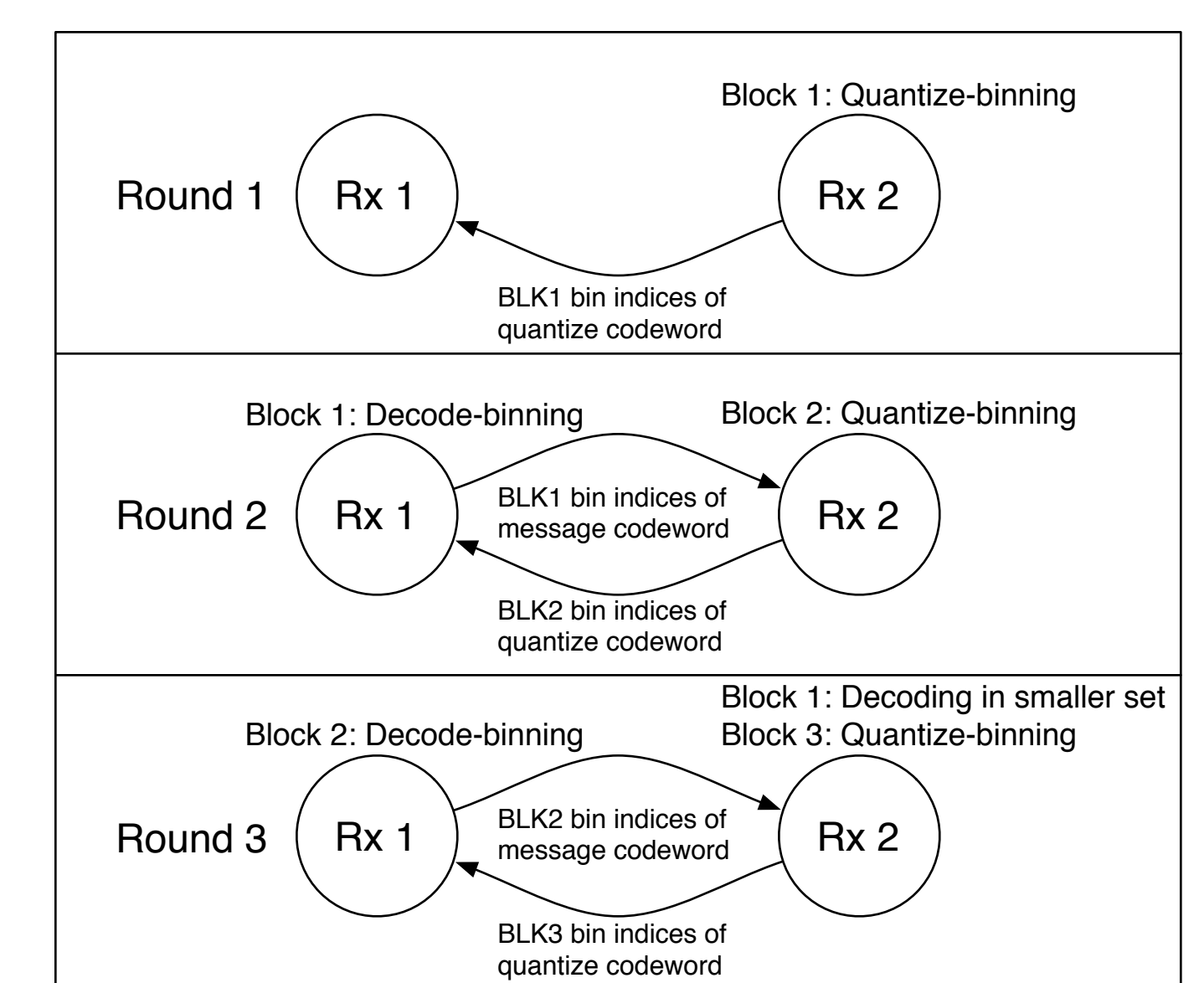
$$\text{where } \xi_1 = I(\hat{y}_2; y_2 | x_{1c}, x_1, x_{2c}, y_1).$$

- One-round vs. Two-round conference:**

One-round



Two-round



## References

- [Han and Kobayashi '81]  
T. S. Han and K. Kobayashi, "A new achievable rate region for the interference channel," IEEE Transactions on Information Theory, vol. 27, pp. 49–60, January 1981.
- [Etkin et al. '08]  
R. Etkin, D. N. C. Tse, and H. Wang, "Gaussian interference channel capacity to within one bit," IEEE Transactions on Information Theory, vol. 54, pp. 5534 – 5562, December 2008.
- [Wang and Tse '09]  
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