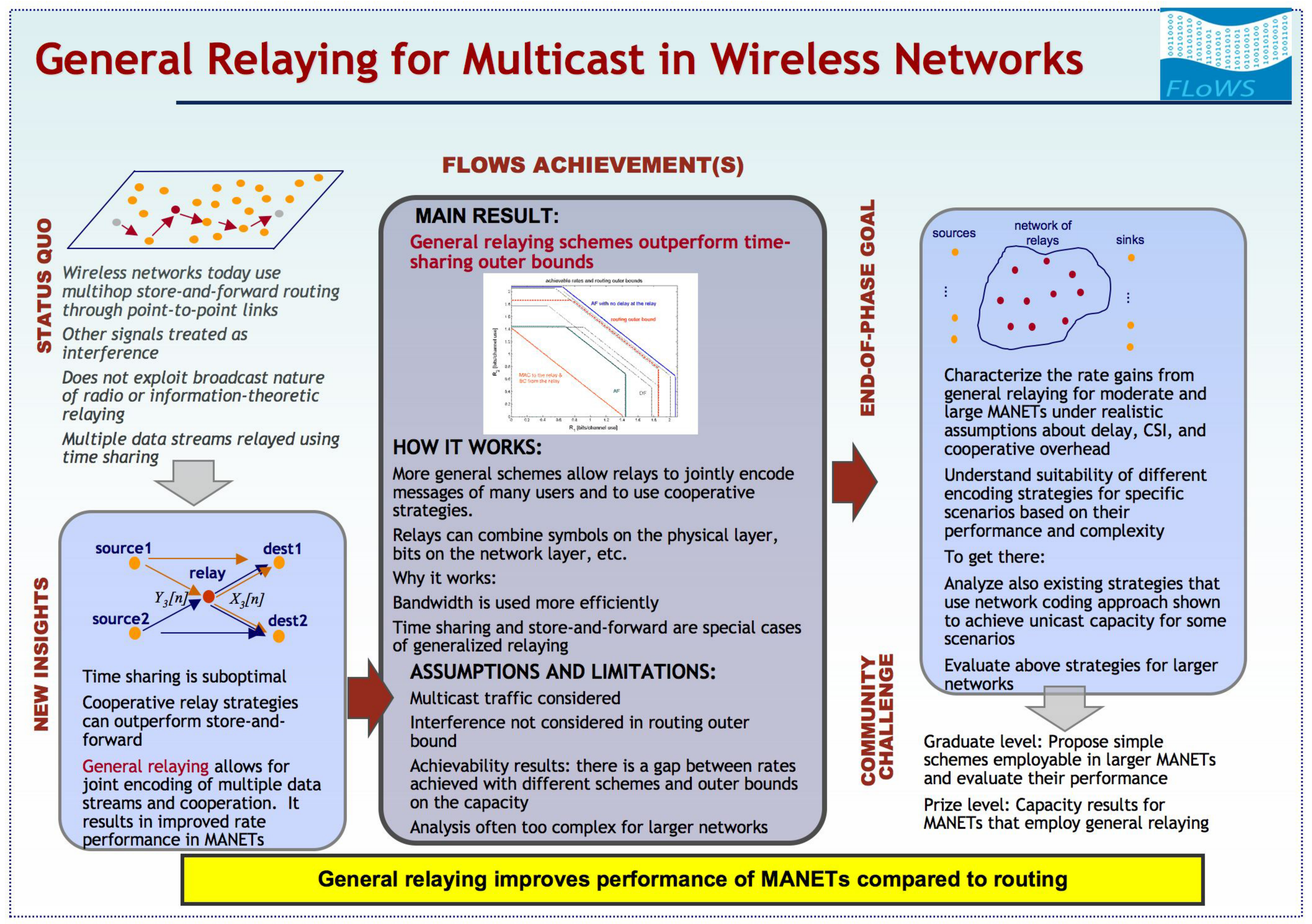
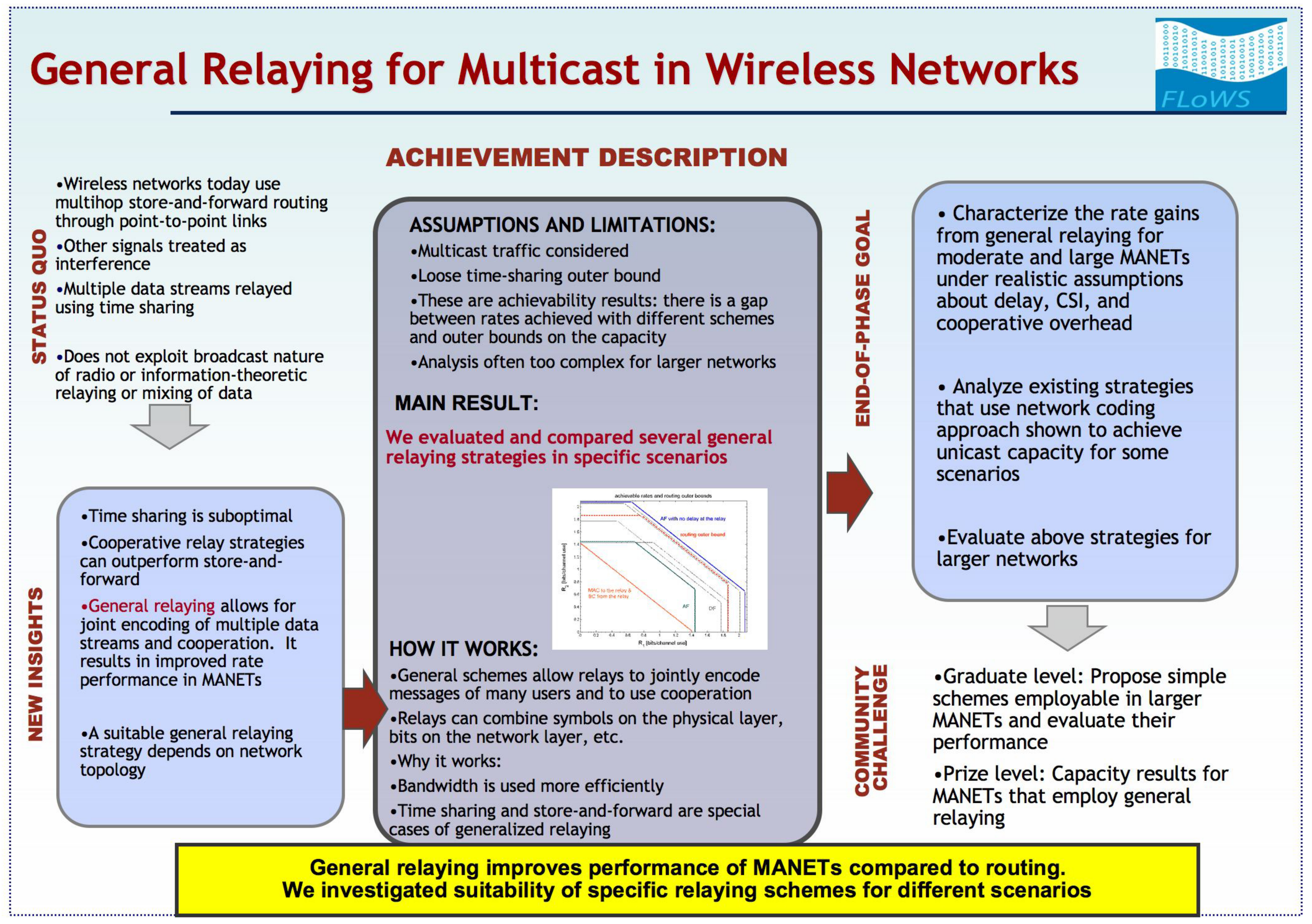
General Relaying for Multicast in Wireless Networks

Ivana Marić, Andrea Goldsmith and Muriel Mėdard

July Summary



December Summary

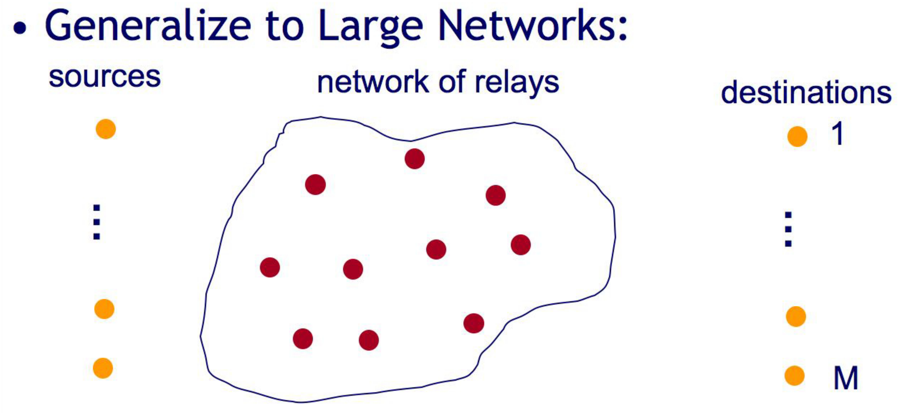


Goals, Progress and Future Work

- GOALS: Analyze general relaying which allows combining of data streams at the relays for multicast in wireless networks
- Can such schemes outperform the time-sharing approach?
- Which of the general encoding schemes has the best performance?

PROGRESS SINCE JULY: Evaluation and comparison of several joint encoding schemes

- FUTURE:
- Generalize to Large Networks:

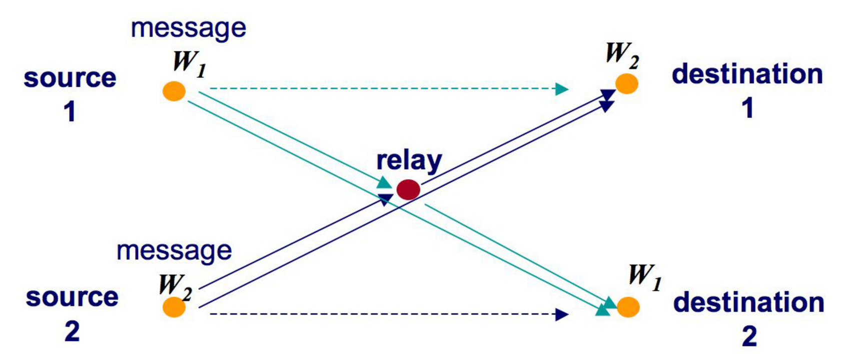


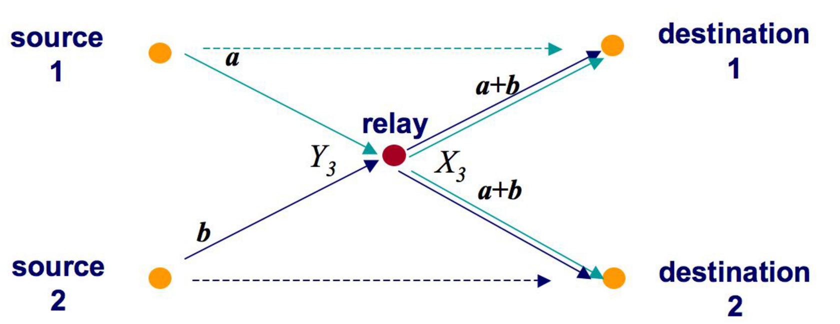
- Relay strategies such as block Markov encoding, sliding-window decoding, backward decoding become very involved in larger networks
- Proposed joint encoding scheme, i.e., analog network coding) is simple ⇨ The achievable rates of the same coding scheme can be evaluated in a large network with M>2 destinations

Further work on small networks: - Obtain tighter bounds on the performance

- Further explore and propose cooperative schemes that incorporate joint relaying and network coding and result in improved or optimal performance

Time-Sharing vs. Joint Encoding





- Traditional communication in wireless networks: multihop through logical point-to-point links
  - Other signals treated as interference
- Cooperative relaying strategies improve performance
  - Nodes do not discard interfering signals
  - Nodes cooperatively encode
- How to handle multiple streams?
- One approach: time-sharing
- Relay switches between forwarding two streams as in routing, but employs cooperative strategies instead of store-and-forward

- We want to consider general relaying which allows for combining data

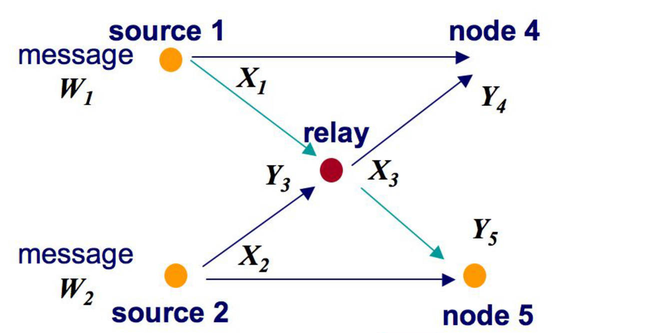
$$X_3[n] = f_n(Y_3[n-1] \dots, Y_3[1])$$

Such as:

- Joint encoding of messages of multiple sources
- Combining of symbols on the physical layer
- Combining of bits on the network layer

Channel Model

Compound Multiaccess Channel with Dedicated Relay



$$Y_3 = h_{13}X_1 + h_{23}X_2 + Z_3$$

$$Y_4 = h_{14}X_1 + h_{24}X_2 + h_{34}X_3 + Z_4$$

$$Y_5 = h_{15}X_1 + h_{25}X_2 + h_{35}X_3 + Z_5$$

- Smallest relevant multicast network
- Includes broadcasting and interference
- Power constraints at the nodes

Cooperative Strategies

1) Amplify-and-forward/*analog* network coding:

$$X_3[n] = \alpha Y_3[n-1]$$

- This combines two data streams since:

$$X_3[n] = \alpha(h_{13}X_1[n-1] + h_{23}X_2[n-1] + Z_3[n-1])$$

- Received at the destination t:

$$Y_t[n] = h_{1t}X_1[n] + \alpha h_{13}h_{3t}X_1[n-1] + h_{2t}X_2[n] + \alpha h_{23}h_{3t}X_2[n-1] + W_t[n]$$

- Achievable rates follow from the capacity of MAC with ISI *[Cheng& Verdu, 1993]*

2) Amplify-and-forward with no delay at the relay:

$$X_3[n] = \alpha Y_3[n]$$

4) MAC/BC approach:
Sources transmit to the relay only.
Relay decodes and broadcasts (W_1, W_2) to destinations using a single codebook. Rates constrained by the worse relay-destination channel.

3) Decode-and-forward:
Source t encodes using superposition coding

$$X_t = \sqrt{P_t}(\sqrt{\alpha_t} V_t + \sqrt{(1-\alpha_t)} Q_t)$$

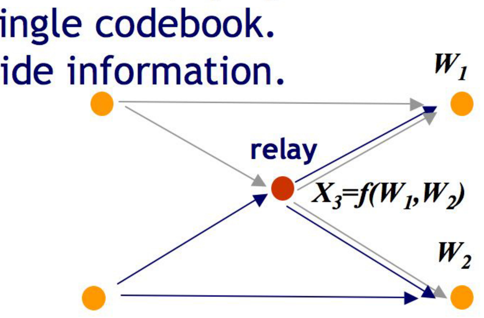
Relay decodes (W_1, W_2) and encodes with two codebooks

$$X_3 = \sqrt{P_3}(\sqrt{\beta} V_1 + \sqrt{(1-\beta)} V_2)$$

$$0 \leq \alpha_1, \alpha_2, \beta \leq 1$$

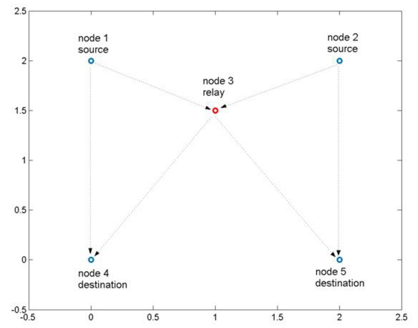
- Achievable rates follow from rates for MAC-DR *[Kramer & Wijngaarden, 2000]*

5) Network coding approach:
Sources time share in transmitting.
Destination t decodes W_t.
Relay decodes and broadcasts (W_1, W_2) to destinations using a single codebook.
Destinations exploit side information.



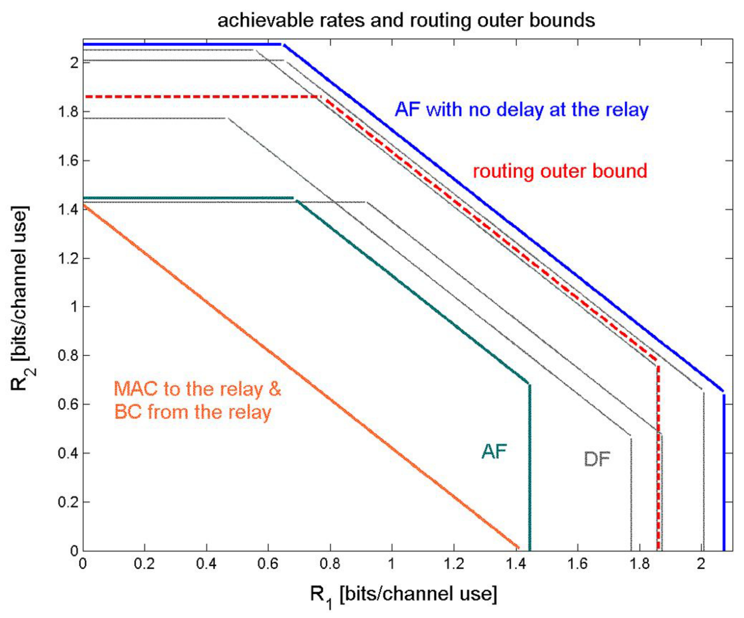
Numerical Comparisons and Observations

Achievable Rates and Time Sharing Outer Bound

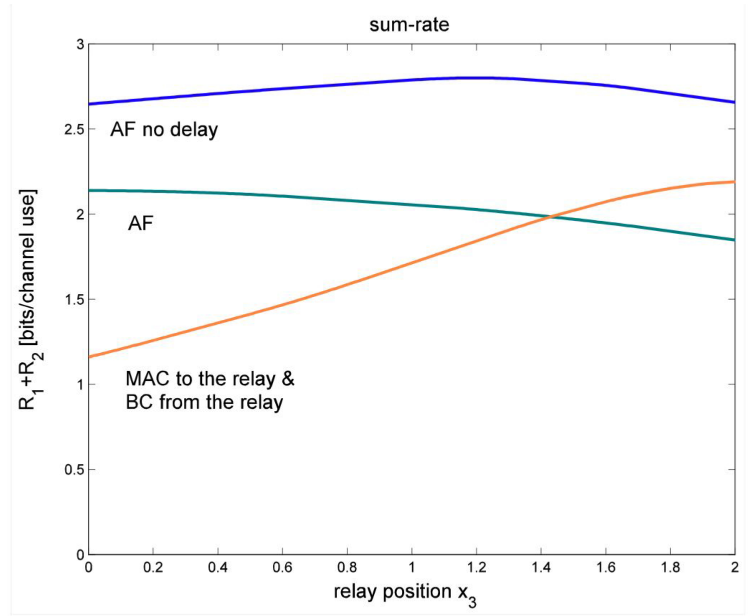


- Symmetric scenario:

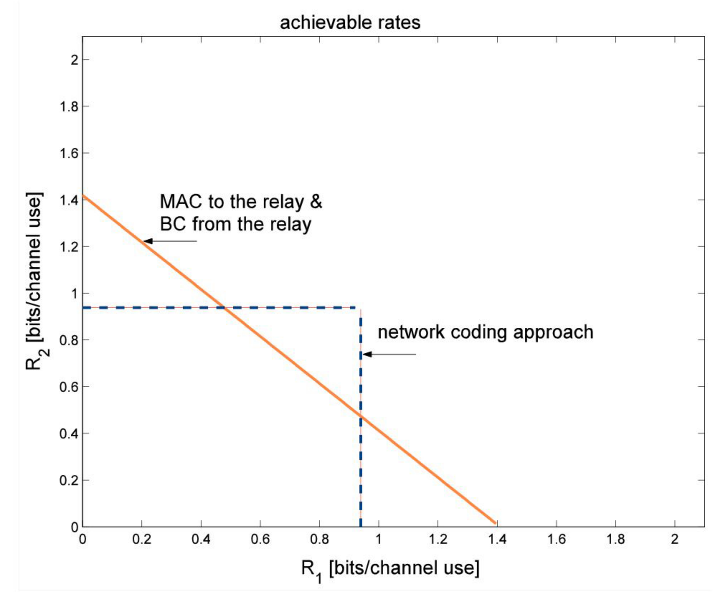
$$P_1 = P_2 = 5P_3$$



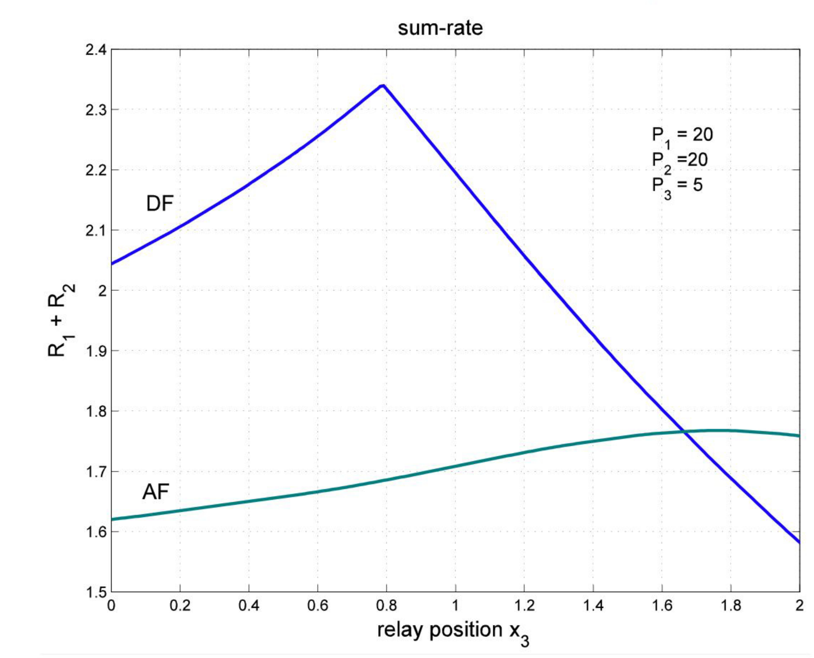
Sum-Rate Performance



Achievable Rates



Sum-Rate in Half-Duplex



- DF outperforms AF and time-sharing outer bound
- AF outperforms outer bound only for no delay at the relay
- Sum rate bound obtained from Fano's inequality
- Time sharing outer bound loose for two reasons:
  - Due to a genie: no interference at receivers
  - Relay knows W_2 a priori
- AF outperforms MAC/BC approach for most of the relay positions
- Half-duplex scenario: DF superior than AF in terms of sum-rate as long as relay is further away from destinations