Introduction

● Fundamental classifications:
  – Amplify-and-forward (AF) vs. decode-and-forward (DF)
  – Relaying modes:
    - Full Duplex (FD)
      • Loop interference
      • Fixed infrastructure relays
      • Separate rx and tx antennas
      • Loop cancellation algorithms
    - Half Duplex (HD)
      • Pre-log 1/2 in capacity
      • Mobile relays and cooperative communication
      • Single antenna is enough

What is the benefit of choosing the proper mode? When is the full-duplex mode feasible? How does power allocation affect the performance?

End-to-end capacities

● The system model:
  - Full Duplex:
    \[
    c_{\text{FD}}^S = \log_2 \left( 1 + \frac{P_S h_{SR} h_{RD}}{N_0 + P_R h_{RD} h_{SR}} \right)
    \]
  - Half Duplex:
    \[
    c_{\text{HD}}^S = \log_2 \left( 1 + \frac{P_S h_{SR} h_{RD}}{P_R h_{RD} h_{SR} + N_0} \right)
    \]

● Power allocation (PA)
  - Uniform power allocation: \( P_S = P_R = 1 \)
  - Individual constraints:
    \[ \text{PA}: \left\{ P_S, P_R \right\} = \arg \max_{\left\{ P_S, P_R \right\}} \left\{ c_{\text{PA}}^S \right\} \text{ subject to } p_S \leq 1 \text{ and } p_R \leq 1 \]
  - A sum constraint:
    \[ \text{SC}: \left\{ P_S, P_R \right\} = \arg \max_{\left\{ P_S, P_R \right\}} \left\{ c_{\text{SC}}^S \right\} \text{ subject to } p_S + p_R \leq 2 \]
  - Closed-form expressions for \( p_S \) and \( p_R \) in the paper

● Comparison of the relaying modes:

Break-even loop interference

● Two extremes for the trade-off:
  - \( C_{\text{FD}}^S = 2C_{\text{HD}}^S \) with protocol \( \pi \in \{ \text{AF, DF} \} \) if \( \gamma_{11} = 0 \)
  - \( C_{\text{FD}}^S / C_{\text{HD}}^S \) is continuous and monotonically decreasing
  - \( \lim_{\gamma_{11} \to \infty} C_{\text{FD}}^S / C_{\text{HD}}^S = 0 \)
  - There exists a break-even loop interference level \( \gamma_{11} = \gamma_{11}^{\text{BE}} \)

Determine \( \gamma_{11}^{\text{BE}} \) for protocol \( \pi \in \{ \text{AF, DF} \} \) such that \( C_{\text{FD}}^S \geq C_{\text{HD}}^S \) if and only if \( \gamma_{11} \leq \gamma_{11}^{\text{BE}} \)

● Uniform power allocation \( (\gamma_{11} \geq 1 - 0 \text{dB}) \)
  - Amplify-and-forward: \( t_{\text{AF}} = 1 - \frac{1}{\frac{1}{2} + \frac{1}{2} + \frac{1}{2} + 1} \)
  - Decode-and-forward: \( t_{\text{DF}} = \frac{1}{\frac{1}{2} + \frac{1}{2} + \frac{1}{2} + 1} \)

● Power allocation with individual constraints
  - Amplify-and-forward \( t_{\text{AF}}^{\text{ind}} \)
    \[ \gamma_{11}^{\text{BE}} = \gamma_{11}^{\text{BE}} \left\{ \frac{1}{\frac{1}{2} + \frac{1}{2} + \frac{1}{2} + 1} \right\} \]
  - Decode-and-forward \( t_{\text{DF}}^{\text{ind}} \)
    \[ \gamma_{11}^{\text{BE}} = \gamma_{11}^{\text{BE}} \left\{ \frac{1}{\frac{1}{2} + \frac{1}{2} + \frac{1}{2} + 1} \right\} \]

● Power allocation with a sum constraint
  - Amplify-and-forward \( t_{\text{AF}}^{\text{sum}} \)
    \[ \gamma_{11}^{\text{BE}} = \gamma_{11}^{\text{BE}} \left\{ \frac{1}{\frac{1}{2} + \frac{1}{2} + \frac{1}{2} + 1} \right\} \]
  - Decode-and-forward \( t_{\text{DF}}^{\text{sum}} \)
    \[ \gamma_{11}^{\text{BE}} = \gamma_{11}^{\text{BE}} \left\{ \frac{1}{\frac{1}{2} + \frac{1}{2} + \frac{1}{2} + 1} \right\} \]

Illustration of above expressions:

Contour plots for the capacity ratio \( \frac{C_{\text{HD}}^S}{C_{\text{FD}}^S} \) when \( \gamma_{11} = \text{dB} \) in the full-duplex mode. 
Contour plots for the break-even loop interference level \( \gamma_{11}^{\text{BE}} \) when \( \gamma_{11} = \text{dB} \).