Power Allocation and Relay Selection in Amplify-and-Forward Relaying

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Overview

- Introduction
- Relaying Schemes
- Power Allocation
- Relay Selection
- Interdependence of above
- Future Work

Introduction

- D2D and Relaying cooperative communications will play important roles in future generation wireless networks.
- Current standard allows deployment of fixed relays to help cell-edge users.
- Advanced cellular relaying modes like mobile relaying, multi-hop relaying, and user-assisted relaying are expected in 5G systems.
- We will discuss the signalling mechanisms in PDF and AF relaying schemes
- We will discuss power allocation and relay selection in AF scheme

Partial Decode-and-Forward Relaying

Two Phases

Total transmission period is divided into phases: 1. Broadcast phase and 2. Multicast phase as shown in the figure below.

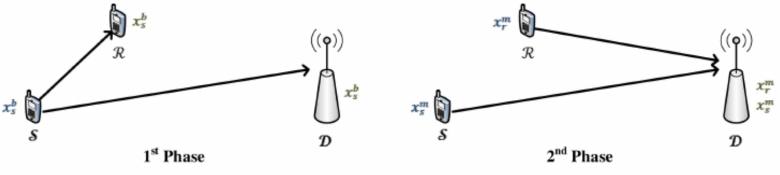

Figure: Two phases in PDF relaying.

Partial Decode-and-Forward Relaying

Transmit Signals

Source uses superposition coding and splits its information into a common part(U_s^b) and a private part(V_s^m)

The signals transmitted by source and relay are as follows:

$$\begin{aligned} \text{Phase 1:} \quad & x_s^b = U_s^b, \\ \text{Phase 2:} \quad & x_r^m = U_s^m, \\ & x_s^m = U_s^m + V_s^m \end{aligned}$$

Partial Decode-and-Forward Relaying

Received Signals

Signals received at relay, BS during broadcast(b) and multicast(m) phases:

$$Y_r^b = h_{sr} x_s^b + Z_r^b, \quad Y_d^b = h_{sd} x_s^b + Z_d^b$$

Z_r^b and Z_d^b are *i.i.d* $\mathcal{CN}(0, \sigma^2)$ that represent noises at $\mathcal{R}$ and $\mathcal{D}$.

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$$Y_d^m = h_{sd} x_s^m + h_{rd} x_r^m + Z_d^m$$

The above expression is true only if $\mathcal{D}$ has knowledge about the phase offset between $\mathcal{S}$ and $\mathcal{R}$.

Amplify-and-Forward

Two Slots

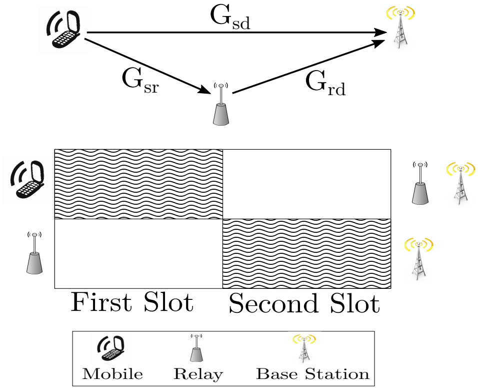

Figure: Two phases in AF relaying.

Amplify-and-Forward

Received Signals

Signals received at relay, BS during the two slots:
First Slot:

$$Y_{sd} = \sqrt{P_s G_{sd}} X_s + n_{sd}$$
$$Y_{sr} = \sqrt{P_s G_{sr}} X_s + n_{sr}$$

Second Slot:

$$Y_{rd} = \sqrt{P_r G_{rd}} X_{rd} + n_{rd}$$

Where $X_{rd} = \frac{Y_{sr}}{|Y_{sr}|}$

The rate/capacity of AF relaying scheme is given by

$$R = \frac{1}{2} w \log_2(1 + \Gamma_{sd} + \Gamma_{rd})$$

where Γ represents SNR

Substituting Γ_{sd} and Γ_{rd}, we get

$$R = \frac{1}{2} w \log_2 \left(1 + \frac{P_s G_{sd}}{\sigma^2} + \frac{P_s G_{sr} P_r G_{rd}}{\sigma^2(\sigma^2 + P_s G_{sr} + P_r G_{rd})} \right)$$

Power Allocation

Single relay case

- Find the source power that maximises rate under given power constraints

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- Prove that rate is concave function of source power

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Single relay case

- Find the source power that maximises rate under given power constraints
- Prove that rate is concave function of source power
- Use Lagrange multiplier method to find optimal power

Power Allocation

Multiple relays

Depends on the relay

Relay Selection

Many relay selection schemes. One of them:

Select relay k where

$$k = \arg\max_i \min\{G_{sr_i}, G_{r_i d}\}$$

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A smoother version of the above would be

$$k = \arg\max_i \frac{G_{sr_i} G_{r_i d}}{G_{sr_i} + G_{r_i d}}$$

Relay Selection

Optimal Scheme

An optimal scheme should use SNR as the deciding parameter

In our case

Select relay k where

$$k = \arg\max_i \Gamma_{r_i d}$$

where $\Gamma_{rd} = \frac{P_s G_{sr} P_r G_{rd}}{\sigma^2(\sigma^2 + P_s G_{sr} + P_r G_{rd})}$

Interdependence

Power allocation and relay selection mutually dependent Can

different relays be optimal at different source powers?

consider two relays R_1 and R_2 and assume both use same constant relay power P_r. Γ_{rd} can be rewritten as

$$\Gamma(P_s) = \frac{P_s ab}{1 + P_s a + b}$$

where $a = \frac{G_{sr}}{\sigma^2}$ and $b = \frac{P_r G_{rd}}{\sigma^2}$
We want to know if at some power P_1, R_1 is a better relay than R_2 i.e.,
$\Gamma_1(P_1) > \Gamma_2(P_1)$
then can R_2 be a better relay than R_1 for some other power P_2?
$\Gamma_1(P_2) < \Gamma_2(P_2)$

let us find the power at which both relays are equally good.

$$\Gamma_1(P_0) = \Gamma_2(P_0)$$

Solving the above equation, we get

$$P_0 = (1 + b_1)(1 + b_2)\frac{\frac{a_1 b_1}{1+b_1} - \frac{a_2 b_2}{1+b_2}}{a_1 a_2 (b_2 - b_1)}$$

For P_0 to be positive, both numerator and denominator should have same sign i.e., if $\frac{a_1 b_1}{1+b_1} > \frac{a_2 b_2}{1+b_2}$ then $b_2 > b_1$. To explain this intuitively, let us assume b_1, b_2 to be much larger than 1 which reduces the first inequality to $a_1 > a_2$. What this means is, source to relay channel is better for R_1 but relay to destination channel is stronger for R_2. Hence at low source powers R_1 gives better SNR but for source power greater than P_0, R_2 is a better relay than R_1. Same argument can be made for the case where inequalities are in the opposite direction.

For $P_0 < 0$, one of the relays is the desired one irrespective of source power.

To summarise, here are the conditions under which one relay is better than the other:

- $\frac{a_1 b_1}{1+b_1} > \frac{a_2 b_2}{1+b_2}$ and $b_2 > b_1$
  R_1 at source power less than P_0 and R_2 at power greater than P_0
- $\frac{a_1 b_1}{1+b_1} < \frac{a_2 b_2}{1+b_2}$ and $b_2 < b_1$
  R_2 at source power $< P_0$ and R_1 at power $> P_0$
- $\frac{a_1 b_1}{1+b_1} < \frac{a_2 b_2}{1+b_2}$ and $b_2 > b_1$
  R_2 is a better relay for all source powers
- $\frac{a_1 b_1}{1+b_1} > \frac{a_2 b_2}{1+b_2}$ and $b_2 < b_1$
  R_1 is a better relay for all source powers

- Assume an initial source power

- Select the best relay at this power
- Solve the optimisation problem
- Check if the current relay is still the best
- If not use the other relay

Future Work

- Will the above method work?

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- Extend it to the case where there are more than two relays

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- Extend it to the case where there are more than two relays
- Power allocation at relay

Thank You