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

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Overview

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

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.

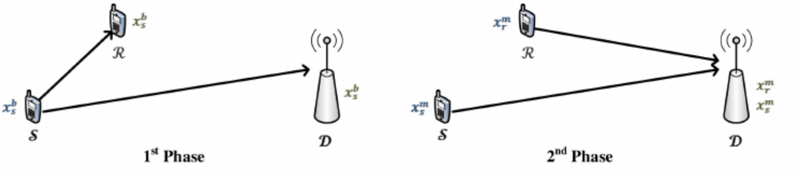

Figure: Two phases in PDF relaying.

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:

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

Amplify-and-Forward

Two Slots

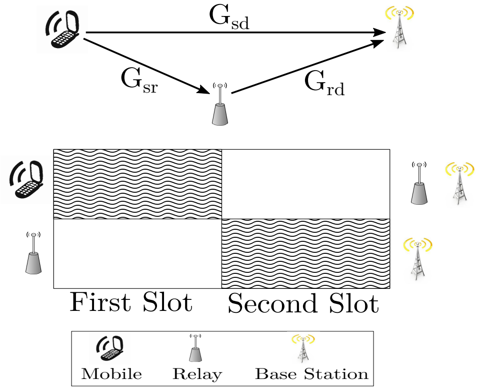

Figure: Two phases in AF relaying.

Amplify-and-Forward

Received Signals

Signals received at relay, BS during the two slots:

First Slot:

$$
\begin{aligned}
Y_{sd} &= \sqrt{P_s G_{sd}} X_s + n_{sd} \\
Y_{sr} &= \sqrt{P_s G_{sr}} X_s + n_{sr}
\end{aligned}
$$

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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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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Select relay k where

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

A smoother version of the above would be

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

Relay Selection

Ideal Scheme

An ideal 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 are mutually dependent

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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

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

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For $P_0 < 0$, one of the relays is the desired one irrespective of source power.
If $P_0 > 0$, then one of the relays gives more SNR at source powers $< P_0$ and the other relay at powers $> P_0$

Let us consider one of the cases in which $P_0 > 0$

$$\frac{a_1 b_1}{1+b_1} > \frac{a_2 b_2}{1+b_2} \text{ and } b_2 > b_1$$

Assume $b_1, b_2 >> 1$
First inequality: $a_1 > a_2$.
What do these conditions mean? 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.

- $\frac{a_1 b_1}{1+b_1} > \frac{a_2 b_2}{1+b_2}$ 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

Power Allocation

- 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?
  Remains to be seen if the above solution converges

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- Will the above method work?
  Remains to be seen if the above solution converges
- Power allocation at relay