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

Prudhvi Porandla Prof. Prasanna Chaporkar
Electrical Engineering
Indian Institute of Technology Bombay

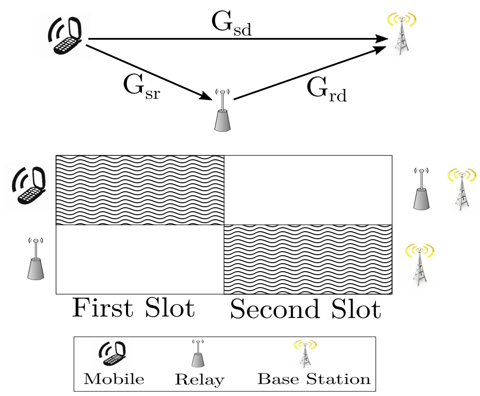

Fig. 1. Two slots in AF

***Abstract*—Multihop communication is considered to be a standard in next generation cellular networks. There are several relaying schemes, Decode-and-forward(DF) and Amplify-and-Forward(AF) being the popular ones. In DF scheme, the relay decodes the message from the source, re-encodes and transmits it to the destination node whereas in AF the relay amplifies the received signal and transmits to the destination node. Relay selection and optimal power allocation are two important aspects in either scheme. In this work, we look at these two problems in 2-hop communication network in which relays employ AF scheme. However, when there are multiple relays the power allocation might interfere with relay selection. We show that this is indeed the case and discuss the conditions under which a relay switch over can take place.**

I. Introduction

A. Subsection Heading Here

Subsection text here.

1) Subsubsection Heading Here: Subsubsection text here.

II. Amplify-and-Forward Relaying

Consider 2-hop relaying; we have a source node, the destination, and a relay node. In amplify-and-forward(AF) relaying scheme, the total transmission period is divided in to two slots. In the first slot, source node broadcasts the message to relay and destination nodes and in the second the relay amplifies the received signal and retransmits it to the destination node. This is illustrated in fig 1.

A. Received Signals

The signals received at relay and destination nodes in the two slots are as follows:
First Slot:

$$Y_{sd} = \sqrt{P_s G_{sd}} X_s + n_{sd} \tag{1}$$

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

Second Slot:

$$Y_{rd} = \sqrt{P_r G_{rd}} X_{rd} + n_{rd} \tag{2}$$

$$Y_{rd} = \frac{\sqrt{P_r G_{rd} P_s G_{sr}}}{\sqrt{P_s G_{sr} + \sigma^2}} X_s + \frac{\sqrt{P_r G_{rd}}}{\sqrt{P_s G_{sr} + \sigma^2}} n_{sr} + n_{rd} \tag{3}$$

The final expression for Y_{rd} is obtained by substituting $X_{rd} = \frac{Y_{sr}}{|Y_{sr}|}$ in eq. 2. All symbols have usual meanings - s denotes source, P denotes power, $G_{sd}(= \frac{g_{sd}}{d_{sd}^2})$ is the channel gain from source to destination, etc.

B. Rate

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}, obtained from equations 1 and 3 respectively, in the above expression we get

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

III. Source power and Relay selection

When there are multiple relays we have to select one of them for transmission. There are various relay selection techniques one of which is Max-Min selection- relay i which maximizes min$\{G_{sr_i}, G_{r_i d}\}$ is selected - and a continuous version of this scheme which uses harmonic mean of $G_{sr_i}, G_{r_i d}$ instead of *min*. However, these are not optimal schemes in the sense that the resulting relay may not give the highest possible rate. An optimal scheme will select a relay which gives maximum rate i.e., relay k is selected where

$$k = \arg\max_i \Gamma_{r_i d} \tag{4}$$

Since Γ_{sd} is same for all relays, this scheme selects the optimal relay.

Now that we've selected a relay for transmission the next step is to optimise the source power P_s. But changing P_s changes Γ_{rd} as well therefore it may so happen that different relays are optimal at different source powers. To see if this scenario is possible, consider two relays R_1 and R_2 and assume both use same constant power P_r. Γ_{rd} can be rewritten as

$$\Gamma(P_s) = \frac{P_s ab}{1 + P_s a + b} \tag{5}$$

where $a = \frac{G_{sr}}{\sigma^2}$ and $b = \frac{P_r G_{rd}}{\sigma^2}$ Now the question can be reframed as: 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. To answer this 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

$$P_0 = (1 + b_1)(1 + b_2) \frac{\frac{a_1 b_1}{1+b_1} - \frac{a_2 b_2}{1+b_2}}{a_1 a_2 (b_2 - b_1)} \tag{6}$$

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_0, 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_2 gives better SNR but if we increase source power beyond 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.

Finally the algorithm to use when there are two relays is:

- Assume some initial source power and select the best relay at that power and optimise the source power
- If the inequalities mentioned above are not satisfied then the problem is solved - we have selected the best relay and we have optimised the power
- Otherwise, check if the current relay is still the best relay. If it is not, then use the other relay and optimise the power

IV. Future Work

The first question that needs to be answered is whether or not the above algorithm converges. In this work we assumed that all relays are transmitting at same constant power,

V. Conclusion

In this work, we have shown that relay selection and source power control problems are not independant and explained briefly under what conditions they are independent. We also proposed an algorithm that can be used to find the best relay and the optimised source power when there are multiple relays.

References

[1] Chandradeep Singh, Prasanna Chaporkar, and S. N. Merchant, *Optimal Power Allocation at Mobile Node for Amplify Forward Relay Transmission*