DYNAMIC RESOURCE ALLOCATION FOR THE BROADBAND RELAY CHANNEL

Kagan Bakanoglu, Deniz Gunduz and Elza Erkip
Electrical and Computer Engineering Department
polytechnic UNIVERSITY

Introduction

- Cooperating mobiles in a wireless network can form a virtual antenna array to obtain spatial diversity. This results in a more robust system against channel variations in a fading environment.
- In this work, we assume partial CSIT in the form of fading channel amplitudes and dynamically allocate the resources in a broadband relay channel.
- Several transmission strategies are possible for broadband relay channel.
- We use the delay-limited capacity and the outage probability as the performance metric of the system.

Performance Metrics

- Delay-Limited Capacity: the highest error free transmission rate for a fading channel when a delay limitation is imposed on the transmission.
- Outage Probability: In time-varying channels, delay limitations imposed by the application (voice, multimedia, etc.), may result in outages when the power budget does not support delay-limited capacity. This corresponds to the cases at which the channel capacity is below the transmission rate.

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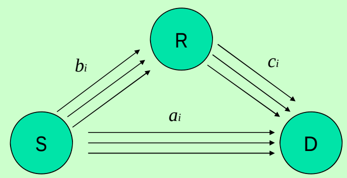
System Model

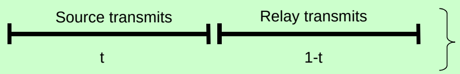
- L parallel, independent flat Rayleigh fading subchannels,
- All channel state amplitudes are available at the source, the relay and the destination,



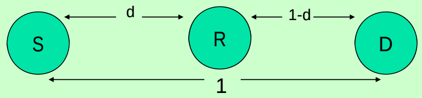
- Only the receivers have the phase information,

Relay cannot transmit and receive simultaneously (half duplex relay),

- Relay utilizes decode-and-forward if utilized,
- Transmission time slot is divided into two, t and 1-t, which are the transmission times of the source and the relay,



- We impose total average power constraint, Pavg among the source and the relay.
- We model the relative distances as seen below:



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Our goal is to allocate the power of the system and portions of the transmission times.

- We investigate the minimum total power for each realization of the channels

$$\min P_{total} \quad \text{such that} \quad C \geq R$$

- Computing the solution P_{total}^* for all R gives us the **delay limited capacity**.
- To minimize the **outage probability**, we use the (P_{total}^*, R) pairs with a power threshold.

Optimum resource allocation:

- When $P_{total}^* < P_{threshold}$ set $P_{total} = P_{total}^*$
  - $P_{total}^* > P_{threshold}$ Do not transmit
- Compute $P_{threshold}$ such that $EP_{total} \leq P_{average}$ where expectation is with respect to all channel realizations.

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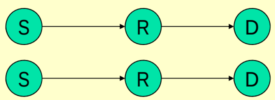
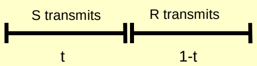
Multihop Transmission (MH)

MH1: The relay decodes and forwards the information over each subchannel separately. The destination does not listen to the source.

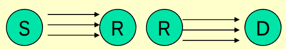


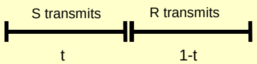


$$C_{MH1} = \sum_{i=1}^{L} \min\{t\log(1+P_{Si}b_i), (1-t)\log(1+P_{Ri}c_i)\}$$

- For each channel realization, the optimum solution for a fixed time allocation is water-filling over the subchannels.
- The optimal time allocation is found numerically.

MH2: The relay reallocates the total rate among the subchannel





$$C_{MH2} = \min\{\sum_{i=1}^{L} t\log(1+P_{Si}b_i), \sum_{i=1}^{L} (1-t)\log(1+P_{Ri}c_i)\}$$

- The solution is found by two water-filling procedures, one from the source to the relay, the other from the relay to the destination.

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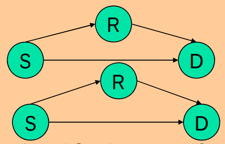
Opportunistic Decode and Forward for Broadband Relay Channel (BODF)

BODF1: We view the broadband relay channel as L separate narrowband relay channels. While one subchannel is used with the relay, another one can be used to transmit directly.

- Each subchannel is operating in opportunistic decode-and-forward (ODF), i.e. the relay is utilized only when it is more power efficient to do so.



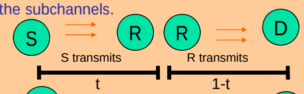
$$C_i^{DT} = \log(1+P_{Si}a_i)$$

$$C_i^{DF} = \min\{ t\log(1+P_{Si}b_i), t\log(1+P_{Si}a_i) + (1-t)\log(1+P_{Ri}c_i)\}$$

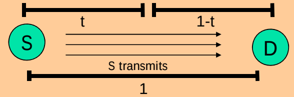
$$C_{BODF1} = \sum_{i=1}^{L} \max\{C_i^{DT}, C_i^{DF}\}$$

BODF2:

- While each subchannel can be used for direct transmission or with the relay, the source and the relay can have different rate allocations over the subchannels.
- For subchannels utilizing relay:



- For subchannels using direct channel:



$$\overline{C}_i^{DF} = \min\{ t\log(1+P_{Si}b_i), t\log(1+P_{Si}a_i) + (1-t)\log(1+P_{Ri}\overline{c}_i)\}$$

$$C_{BODF2} = \sum_{i=1}^{L} \max\{ C_i^{DT}, \overline{C}_i^{DF} \}$$

Due to the complexity of BODF1 and BODF2, we numerically find the minimum total power.

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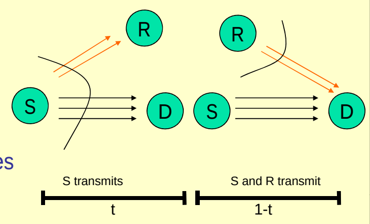
Low complexity BODF

BODF3:

- Total rate is first allocated jointly among all the source to relay subchannels and the source to destination subchannels.
- This allocation is used to decide operating mode of each subchannel
- Based on the decision, total rate is jointly allocated among specified source to relay subchannels and the source to destination subchannels.
- The relay decodes all the received rate and forwards to the destination by reallocating the power
- The power allocation that minimizes the total power is water-filling in the source and the relay



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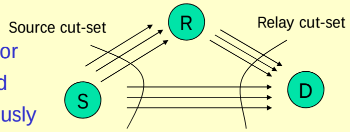
Theoretical Bounds

Upper Bound to the Delay-Limited Capacity

- We use the cut-set bounds for the half-duplex relay for S and R not transmitting simultaneously



$$C^{Source}_{cutset} = \sum_{i=1}^{L} t\log(1+(a_i+b_i)P_{Si})$$

$$C^{Relay}_{cutset} = \sum_{i=1}^{L} (t\log(1+a_iP_{Si}) + (1-t)\log(1+c_iP_{Ri}))$$

$$C_d^{UB} = \sup_{0\le t\le 1} \min\left(C^{Source}_{cutset}, C^{Relay}_{cutset}\right)$$

Lower Bound To Outage Probability

•These cut-set bounds can also be used to find a lower bound to the outage probability.

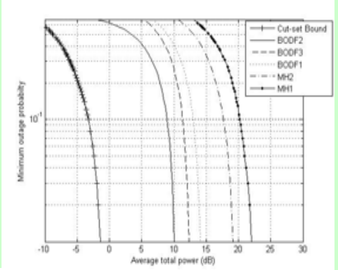
Simulations

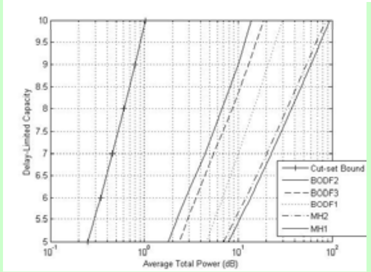
Delay-Limited Capacity vs Average Total Power

- We use L=4 subchannels among each node.
- The distance between the source and the relay is 0.3.

Outage Probability vs Average Total Power

- The target rate is R=10.





Comparison

- BODF uses the direct channel so performs better than MH.
- BODF2 has the best performance among all other transmission strategies. However the solution for BODF2 has high complexity.
- Although BODF3 has less complexity than BODF2, BODF3 performs close to BODF2.
- Reallocation of rates in the relay enhances the performance of the system. This can be seen from the performance difference between BODF1-BODF2 and MH1-MH2.
- There is a gap between cut-set bound and BODF2 since the relay is half-duplex and has same transmission time allocation for all subchannels.

Future Work

- Resource allocation for the parallel relay channel with multiple relays
- Low complexity subchannel allocation algorithm

For more information and related publications, visit http://wireless.poly.edu/