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# RESOURCE ALLOCATION FOR THE PARALLEL RELAY CHANNEL WITH MULTIPLE RELAYS

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## Motivation

- 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 consider a cooperative broadband network where the transmission of two nodes is assisted by many relays.
- Each node uses OFDM and adapts power and rate on each carrier with the aim of maximizing end-to-end rate.
- Achievable rates for finite and infinite number of subcarriers between nodes are investigated.

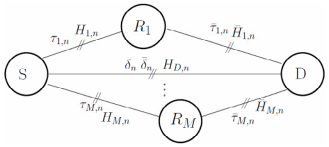
## Model

- A relay network with a source S, a destination node D and M relay nodes $R_m$.
- Channel between nodes are composed of N parallel subchannels.
- Gains are fixed and known to all nodes.
- Relays are half duplex and utilize decode-and-forward (DF).
- Transmission slot is divided into two phases of duration t and 1-t.
- Cooperative combining is done at D.

## Practical Assumptions

- No cooperative beamforming, hence no common information from the source to the relays.
- Each subchannel is allocated to only one node.

## Problem Formulation for Finite Subchannels



- $\tau_{m,n}, \bar{\tau}_{m,n}, \delta_n, \bar{\delta}_n$ :indicators which are 1 if subchannel n is allocated to the corresponding link.
- Achievable rates are:

$$R_D^{DT} = \frac{t}{N}\sum_{n=1}^{N}\delta_n \log_2(1+H_{D,n}P_n) \text{ rate of S-D link in phase 1}$$

$$\bar{R}_D^{DT} = \frac{(1-t)}{N}\sum_{n=1}^{N}\bar{\delta}_n \log_2(1+H_{D,n}\bar{P}_n) \text{ rate of S-D link in phase 2}$$

$$R_m^{DF} = \frac{t}{N}\sum_{n=1}^{N}\tau_{m,n} \log_2(1+H_{m,n}P_n) \text{ rate of S-R}_m \text{ link in phase 1}$$

$$\bar{R}_m^{DF} = \frac{(1-t)}{N}\sum_{n=1}^{N}\bar{\tau}_{m,n} \log_2(1+\bar{H}_{m,n}\bar{P}_{m,n}) \text{ rate of R}_m\text{-D link in phase 1}$$

$$R_{D,m}^{DF} = \frac{t}{N}\sum_{n=1}^{N}\tau_{m,n} \log_2(1+H_{D,n}P_n) \text{ rate from cooperative combining}$$

## Problem Formulation for Finite Subchannels

- **Objective**: $\max R_D^{DT} + \bar{R}_D^{DT} + \min(R_m^{DF}, \bar{R}_m^{DF} + R_{D,m}^{DF})$

  **subject to** the source and relay power constraints.
- Note that each relay can only forward min of phase1 and phase2 rates.

**Theorem 1:** For given subchannel and time allocation, optimal relay power allocation is

$$\bar{P}_{m,n}^{*} = \bar{\tau}_{m,n}\left(1/\bar{\lambda}_m - 1/\bar{H}_{m,n}\right)^{+}$$

where $\bar{\lambda}_m$ is chosen to satisfy power budget for $R_m$.

- Optimal source power allocation is

$$P_n^{*} = \begin{cases} \left(1/\lambda - 1/H_{D,n}\right)^{+} & \delta_n = 1 \\ -B_{m,n}/2 \mp \sqrt{B_{m,n}^{2} - 4C_{m,n}} & \tau_{m,n} = 1 \end{cases}$$

$$\bar{P}_n^{*} = \bar{\delta}_n\left(1/\lambda - 1/H_{D,n}\right)^{+}$$

$$B_{m,n} = 1/H_{m,n} + 1/H_{D,n} - (\mu_m + \eta_m)/\lambda$$

$$C_{m,n} = 1/(H_{m,n}H_{D,n}) - \mu_m/(\lambda H_{D,n}) - \eta_m/(\lambda H_{m,n})$$

- $\lambda, \mu_m$ and $\eta_m$ are chosen to satisfy source power constraint.

## Greedy Resource Allocation Algorithm

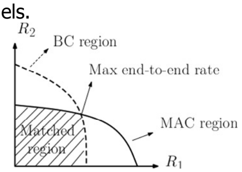
- Start with no subchannel allocation.
- Subchannel which leads the highest end-to-end rate is chosen and allocated to the corresponding node.
- End-to-end rate is evaluated by optimal power allocation given in **Theorem 1.**
- Relay rate mismatch is kept as small as possible since mismatch is not favorable.
- Optimal time allocation is found numerically.

## Infinite Subchannels

- Channel gains are Rayleigh distributed and independent both across relays and across subchannels.
- Full channel statistics are observed.
- The model for this limiting case can also be thought as flat fast fading channel.
- Phase 1 and phase 2 are statistically equivalent to fading broadcast and multiple access channels, (BC) and (MAC) respectively.
- Cooperative coding is not utilized in this limiting case.

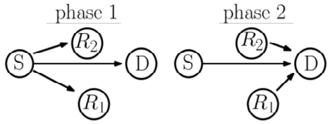
## No Direct Link

- Cascade combination of BC and MAC channels.
- BC and MAC capacity regions are found with initial simplifying assumptions.
- Rate regions are matched and the point maximizing end-to-end rate is found.



## With Direct Link

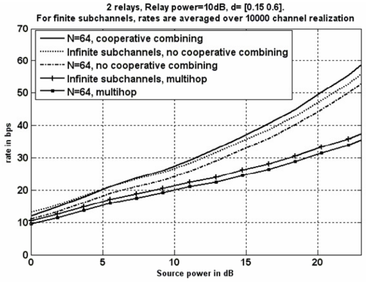
- D and S are treated as virtual relays in phase 1 and phase 2.



- BC and MAC capacity regions are found with initial simplifying assumptions.
- The point where end-to-end rate is maximized is found by numerical approach.

## Numerical Results

- 64 subchannels performs close to infinite subchannels.
- Cooperative combining improves the performance more than infinite number of subchannels.



## Conclusion and Future Work

- An optimization problem for joint power, time and subchannel allocation is formulated to maximize the total end-to-end rate.
- We focus on greedy algorithm which jointly allocates subchannels and power.
- The limiting case where the number of subchannels goes to infinity is studied.
- Resource allocation for infinite number of subchannels case with cooperative combining will be studied as a future work.