Exploiting Multiuser Dynamics in Half-Duplex Wireless Relaying

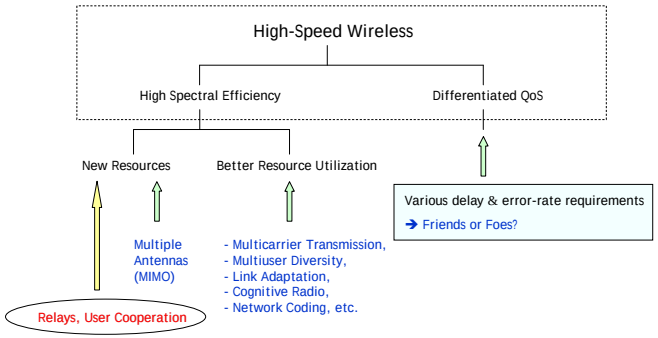
Ernest Lo and Andrea Goldsmith, Wireless Systems Lab, Stanford.

Summary

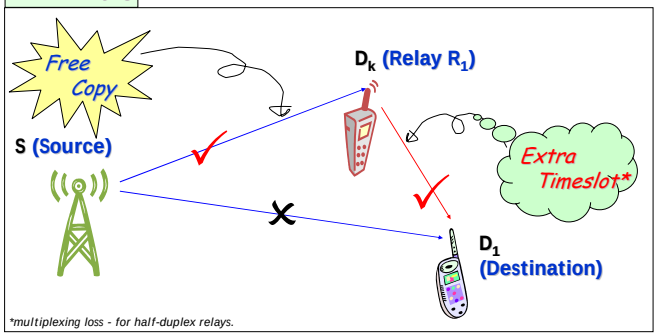
We consider the design of half-duplex wireless relaying protocols with channel knowledge at only receivers:

- **Mixed-User Approach**
  - **users perform relaying on top of each other's direct transmission.**
- **Exploiting Multiuser Dynamics**
  - **1. QoS Alignment**
  - **2. Diversity-Multiplexing-Tradeoff (DMT)-Friendly Interference**
  - **→ confine interference by relays to the time moment when the coexisting user is in outage (no channel prediction required).**
- **Good DMT & Compatibility with Existing Non-Cooperative Systems**

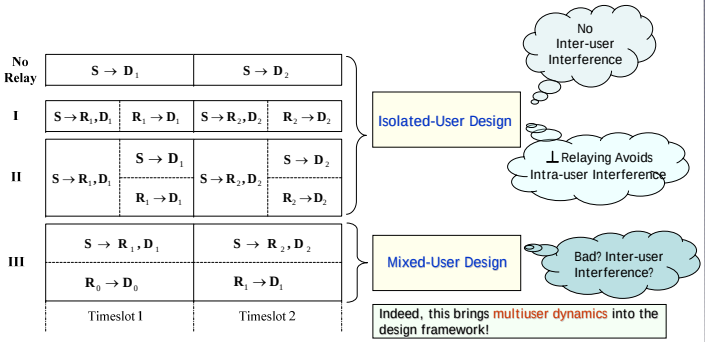
Introduction



Opportunities & Challenges



Interference Management



Various Half-Duplex Protocols for Downlink.

Remark: We consider only channel state information at receivers.

Exploiting Multiuser Dynamics (1)

QoS Alignment

Consider 2 QoS Classes:

Class A – eligible for using relays;

Class B – no privilege/not in need of using relays.

Strategy 1:

A Class-A user (user 1) is paired up with a Class-B non-cooperative (NC) user (user 2) with $R_1 \le R_2$ where user 1 performs relaying during the time of user 2's message transmission.

Property 1:

User 1 earns a free relaying timeslot while leaving User 2 completely unaffected.

$$p_{out} \approx \frac{1}{SNR^d} \quad \text{where} \quad d^{\text{III,S1}}(r) = \begin{cases} 2-3r, & r \in [0,\ 1/2] \\ 1-r, & r \in [1/2,\ 1] \end{cases} \quad \text{or} \quad d^{\text{III,S1}}(r) = 2-2r, \quad r \in [0,\ 1]$$

when Class-B is fixed-power.

Exploiting Multiuser Dynamics (2)

DMT-Friendly Interference

Consider dynamics among Class-A users:

Interference to User 1: $R_0 \to R_1$, $R_0 \to D_1$, $S \to D_1$ (message for D_2)

Strategy 2:

Suppose that the source transmits to Class-A users 1 to K in sequence. Then, user k performs its relaying operation when the source is transmitting to user k+1 with $R_{k+1} \ge R_k$.

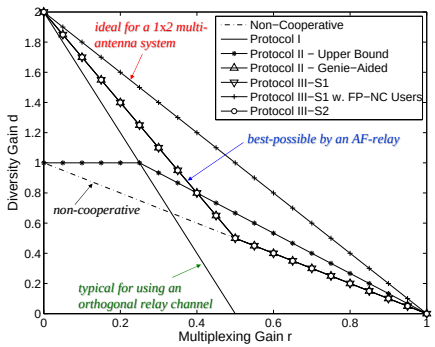
Property 2:

User k earns a free relaying timeslot while leaving User k+1's DMT unaffected.

with the aid of interference cancellation (IC)

$$d^{\text{III,S2}}(r) = \begin{cases} 2-3r, & r \in [0,\ 1/2] \\ 1-r, & r \in [1/2,\ 1] \end{cases}$$

Diversity-Multiplexing Tradeoff (DMT)



Diversity Gain: $d := -\lim_{\rho \to \infty} \frac{\log p_{out}}{\log(\rho)}$

Multiplexing Gain: $r := \lim_{\rho \to \infty} \frac{R(\rho)}{\log(\rho)}$

ρ – SNR; $R(\rho)$ – Rate; p_{out} – Outage Prob.

The proposed scheme: *(PIII with simple DF)*

1. *better* than existing isolated-user designs (PI & PII);
2. at least *as good as* an AF-relay;
3. *ideal DMT* possible.

DMTs of Various Repetition-Type DF Protocols.

Practical Considerations

Compatibility with Existing Network Structure	Practical Coding Scheme	Channel State Information Requirement
Highly Compatible	Simple	Only at Receivers
Full Timeslot: No dynamic nor fixed timeslot adjustment	Single-User Codes: No assumption of independent random codebooks	No CSI Forwarding
Source Transmission Scheme Unchanged: Relay can be introduced at any time upon availability	Simple Diversity-Combining Receivers with one-shot IC: Simple repetition-type DF is good enough	Only Requested Rate Required at Transmitter

Extensions

Possible Extensions:

- dynamic source/relay time adjustment
- power and rate allocation
- interference forwarding
- multiple-antenna nodes
- multi-hop and other network models

Exploiting multiuser dynamics offers a new means of relaying protocol designs, and is compatible with other techniques for further enhancement.