Enhancing Rates in Relay Channels

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INTRODUCTION
Introduction

• Landmark work
  – “Capacity theorem for the relay channel,” [Cover and El Gamal, TIT, 1979].
  – Introduced two fundamental relaying schemes:
    • Decoding and Forward (DF) and Compress-and-Forward (CF).
    • Cut-set bound can be loose: modulo-sum relay channel (Aleksic and Yu, TIT, 2009).

• A generalized DF-CF: superimposes CF on DF
  – **We analyzed it in Gaussian channel (Ch. 2).**
Recent progress

- showed advantage over conventional CF in multimessage network.
- Based on the study of the relay codebook structure, we proposed a new decoding procedure (Ch. 3).
- We analyzed the gain in certain networks (Ch. 4).
• Application in channel with jamming
  – We introduced a “friendly” eavesdropper.
  – We analyzed its role as a CF relay. (Ch. 5)
GENERALIZED DF-CF

TOPIC I
Analysis on Generalized DF-CF

• Related work
  – “Capacity theorem of relay channels,” [Theorem 7] [Cover, El. Gamal, TIT, 1979].

• **Question: Does it provide guaranteed gain?**
Analysis on Generalized DF-CF

- We particularized the abstract channel and codebooks to Gaussian channel and Gaussian codebooks with average power constraint.
- We considered Signal-to-Noise Ratio (SNR) in different regions.
- Using KKT, we analyzed the optimality of this Generalized DF-CF scheme in each SNR region.
We showed that in certain SNR regions, the generalized DF-CF reduces to its underlying DF or CF.

We proved that there exist SNR regions in which generalized DF-CF is guaranteed to provide a gain over both DF and CF.

However, this gain was shown to be upper bounded by 0.5 bits per channel use (bpcu).
Analysis on Generalized DF-CF

• Gaining this insight, we proposed that DF-CF switching can provide substantial rate gain over fixed DF or CF.
• Simulation using quasi-static Rayleigh fading channel confirms the gain.
TOPIC II

EXPLOITING THE N-TO-1 MAPPING IN CF
Exploiting the N-to-1 Mapping in CF

• Related work
Exploiting the N-to-1 Mapping in CF

• Insight into NNC/SNNC
  – Both NNC and SNNC use 1-to-1 mapping as opposed to the N-to-1 mapping inherited in Wyner-Ziv binning in the conventional CF.
  – This implicitly imposes a rate constraint on the relay transmission rate.
  – Rate gain can be obtained in the considered multimessage network.

• Is 1-to-1 mapping necessary?
• Does the general N-to-1 mapping provide gain?
Exploiting the N-to-1 Mapping in CF

• The framework of our approach
  – Conventional CF codebook structure (N-to-1 mapping).
  – Short message encoding.
  – Sliding window forward decoding.
  – Layered decoding structure.
    • Only the codebooks in which unique codewords are found in the joint typicality set at one layer will be considered at the next layer.

• Result
  – Achieves the same rates as NNC/SNNC in the multimessage network.
  – Relaxes the rate constraint on the relay.
Exploiting the N-to-1 Mapping in CF

- Achieving rate gain by the new decoding procedure
  - We consider two networks:
    - DF-CF relay chain network.
    - Partially cooperative network.
  - In both networks, side information is only available to a subset of the receiving nodes in the network.
  - Lower relay transmission rate in these cases provides advantages.
Exploiting the N-to-1 Mapping in CF

- **DF-CF broadcast relay (BR) chain network:**
  - A BR channel with common message and two receivers.
  - A CF relay followed by a DF relay.
    - This setup is similar, to some extent, to a case of the DF-DF relay chain in “Parity forwarding for multiple-relay networks,” [Razaghi and Yu, TIT, 2009].
  - DF does not have direct link from the source.
Exploiting the N-to-1 Mapping in CF

- Partially cooperative multimessage network:
  - A BR channel with common message and two receivers.
  - A CF relay also has its own receiver, which does not have direct link from other nodes in the network.
TOPIC III

APPLICATION IN COMMUNICATION WITH JAMMING
Friendly Eavesdropper Combatting a Gaussian Jammer

- We considered a communication network with a Gaussian jammer.
- We introduced a “friendly” eavesdropper:
  - Picks a jammer’s signal.
  - Assists the communication.
  - Average power constraint and rate limited.
- **What is the optimal signaling strategy?**
  (the max. rate the source can reliably communicate to the receivers)
Friendly Eavesdropper Combatting a Gaussian Jammer

- We analyzed the following signaling strategy:
  - Gaussian codebook.
  - Using CF relaying scheme with our decoding procedure.
- Result: capacity achieving.
Summary of Contributions

• Generalized DF-CF
  – Showed SNR conditions under which the generalization reduces to its underlying DF or CF.
  – Proved the existence of the SNR regions in which generalized DF-CF is guaranteed to provide rate gain over DF and CF.
  – The gain is proved to be upper bounded by 0.5 bpcu.
  – Showed that switching between DF and CF yields substantial gain.

• Exploiting the N-to-1 mapping in CF
  – Generalized the conventional CF.
  – Relaxed relay transmission rate constraint for conventional CF.
  – Showed that in two networks, when side information is only available to a subset of the receiving nodes, the new procedure is able to provide rate gain.
Summary of Contributions

• Communication in the presence of Gaussian jamming
  – Introduced the concept of friendly eavesdropper.
  – Analyzed its role as a CF relay.
  – Showed that Gaussian codebook and CF with our decoding procedure achieve the capacity.
Future Work

• Multimessage network:
  – How can decoding nodes use the information to help other receivers?

• Communication in jamming:
  – Consider generalized DF-CF.
  – Consider channel state information.
• Journal papers

• Conference papers
THANK YOU