Cooperative Communications with Network Coding for Wireless Uplink Channels

Ming Xiao, Communication Theory, EE, KTH

Background

Future wireless systems are characterized by large user capacity, high speed, high reliability. Yet, inherent fading and interference of wireless communications render these design objectives challenging. As an efficient and inexpensive method to combat wireless fading, cooperative communications ([1], [2]) has recently attracted lots of research efforts and practical implementations. The principle of cooperative communications is illustrated in Figure 1. In wireless uplinks, two or more users sending messages to a common base station (BS) form partners to help each other on information transmission. When user 1 communicates to the BS, the relay (partner user 2) also receives the messages for the broadcasting property of the wireless medium. Therefore, the information messages from user 1 are transmitted to the BS through two fading paths: one direct path and one indirect path through relay (user 2). The potential gain provided by the relay includes coverage, cooperative diversity, and increased spectral efficiency [1], [2]. Compared to the traditional MIMO, cooperative communications are not subject to the limitations of antenna size, cost, hardware etc.

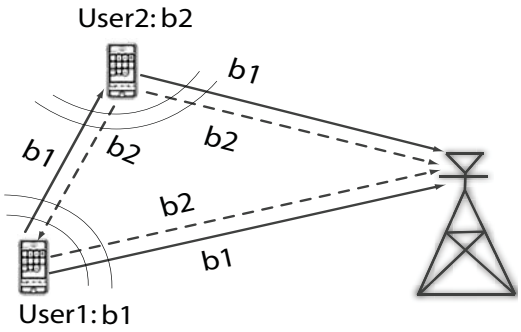

Figure 1.Cooperative communications without network coding.

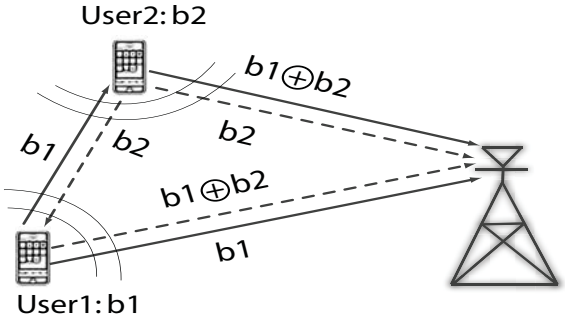

Figure 2. Cooperative communication with network coding.

Currently, most of cooperative communications schemes keep information of different users separate. This is actually a physical-layer routing (detecting, replicating, and forward) approach. As a new strategy of information transmission for multi-hop networks, network coding ([3]) allows messages from different source to be mixed in an intermediate node. Thus, performance gains in e.g., network flow, energy efficiency are obtained. Clearly, the principles of network coding can be used for cooperative communications, for their intriguing connections. There are also some results on network coding for relay channels ([4], [5], [6]]). Yet, these schemes are not general enough. For instance, cooperative communications has more general topologies than relay channels, especially for multiple partners. In [7], network coding is used for two-node cooperative

communications. Yet, the results in [7] are also not general enough in the sense that there is no gain in higher diversity order (thus no asymptotic performance gain), and there are only two users *etc*. Thus, it is valuable to investigate how to efficiently use network coding for cooperative communications. The project content partly fits an on-going joint project with Ericsson research: SERAN (simple and efficient radio access networks) in the framework of VINNOVA ICT-branchforsk program.

Project Description

This project aims at increasing the transmission efficiency e.g., energy efficiency, error probability (BEP: bit error probability, FEP: frame error probability), throughput, network capacity for the uplinks of wireless cooperative networks. One candidate schematic for the two-partner network is shown in Figure 2. In the scheme, the relay performs network coding among partner's message and its own messages. Thus, each message is transmitted via three times through fading channels instead of two (as Figure 1), while the total resource usage is the same. Higher diversity is achieved by network coding. There is also coding gain by mixing information of different users, similar to channel codes with a longer block length. The improvement is more obvious for more partners.

The research approaches include both theory and implementation aspects. For the former, the outage probability and throughput will be studied by mutual information analysis. The latter is mainly performed by BEP or FEP analysis (by union bounds) and Monte Carlo simulations. The results may go to the testbed of EE School, depending on results. To optimize performance, we shall find efficient information procession in partner nodes and base station, from both coding structure and diversity order aspects. Further, optimal combination of various channel coding scheme and network coding, e.g., LDPC, turbo codes, LDGM codes will be exploited.

The project shall contribute to developing the infrastructure of future high-speed, high-reliability, affordable wireless networks. The cooperative communications is regarded as a virtual MIMO, which provides efficient approaches to combat fading without limitation of costs and complexity. Network coding allows the mixture of information from different users. Thus, a higher degree of freedom on design is obtained and higher transmission efficiency is expected.

Project Team and Management

- **Dr. Ming Xiao, project manager, KTH/EE/Communication Theory**
- **Jinfeng Du, GST student, KTH/EE/Communication Theory**
- **One or two Master students from Communication Theory group**

The project management will be carried out in host Communication Theory group at KTH, where excellent research environment and enough administration and hardware resource will be provided to fulfill the project. Financial support on e.g., travel for conference can be obtained from the host group.

References

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