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Monday 15 September 2008, 9am-1pm

Presenter:

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Abstract:

The presence of multiple users in a wireless network offers an opportunity for their cooperation leading to improved overall performance. Cooperative strategies beyond multi-hop routing are expected to bring gains in terms of rate, coverage, reliability and energy-efficiency. This tutorial will present fundamental coding strategies for relay channels with and without fading. Several scenarios in which cooperation leads to optimal performance will be shown. The tutorial will also present cooperative strategies for networks with multiple source-destination pairs. Several methods for managing interference, ranging from coherent cancellation to interference amplification, will be discussed, and implications of these approaches on the design of cognitive radio networks will be presented. The impact of cooperation to scaling laws in large networks will also be shown. Finally, the network architectures required for cooperative communications, and challenges to their practical realization will be discussed.

Motivation:

In recent years there has been a sharp increase in the demand for higher data rates and better coverage. This demand, coupled with the emergence of ad-hoc networks has put the spotlight on cooperative communications as a viable means to boost network performance for current and future wireless networks. The traditional design of wireless networks views the network as a set of point-to-point links. In contrast, cooperative strategies capture the broadcast nature of the wireless multiuser channel and enable general encoding approaches at intermediate nodes leading to improved performance. Cooperative communications will therefore shape the design of future networks such as ad hoc networks, cognitive radio networks, sensor networks, wireless mesh networks, and cellular networks with relays.

Scope and Objective:
The participants will be offered a detailed description of the fundamental strategies with insights and instances in which they can achieve capacity. It will be shown how cooperative strategies increase rates, improve reliability and impact scaling laws in wireless networks. Their impact on the design of future networks will be offered and challenges will be discussed with the goal to motivate future progress in this area of research.

Intended audience:
Researchers interested in the field of wireless communications and multiuser information theory. Network designers interested in networking aspects of cooperative communications and in developing cooperative protocols to implement these ideas. The tutorial requires only basic knowledge of information theoretic quantities such as mutual information and entropy.

Outline:
Section 1 - Introduction. Motivation: the role of cooperation in wireless networks. Information-theoretic models for networks and underlying assumptions. Performance metrics: network capacity region, degrees of freedom, diversity-multiplexing tradeoff, scaling laws. Overview of cooperative schemes: relaying, feedback and conferencing.

Section 2 - Cooperative strategies. Decode-and-forward, compress-and-forward, amplify–and-forward, linear relaying. Scenarios in which they achieve capacity. Cut-set upper bounds.

Section 3 -Conferencing and feedback. System model. Conferencing in multi-access and broadcast channels. Capacity results for feedback channels with and without memory. Benefits of using feedback in networks.

Section 4 –Cooperation and cognition in networks with multiple source-destination pairs. Cooperative strategies for the basic network - the interference channel with a relay. Managing interference via interference forwarding. Cooperation in cognitive radio networks. Transmitter cooperation.

Section 5 - Cooperation in fading channels. Performance metrics: diversity and multiplexing gain, diversity-multiplexing tradeoff. Cooperative diversity. Optimal cooperative schemes. Networks with multiple relays: virtual MIMO and clustering.

Section 6 - Cooperation in large networks. Scaling laws. Achieving the optimal scaling via hierarchical cooperation. Coded vs. uncoded transmission. Erasure networks.

Section 7 – Summary and Challenges. Theoretical results and practical designs. Network architecture for cooperative protocols. Impact of cooperative strategies on to design of future wireless networks.

Bios:

Ivana Marić received her B.S. degree from the University of Novi Sad, Serbia. She finished her M.S and Ph.D. in the Wireless Network Information Laboratory (WINLAB), Rutgers University in 2000 and 2006, respectively. She was a summer intern at ATT Research Labs in 1998. She is currently a postdoctoral scholar at Stanford University. Her research focuses on network information theory and wireless communications.
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Ron Dabora received his B.Sc. and M.Sc. degrees in 1994 and 2000, respectively, from Tel-Aviv University and his Ph.D. degree in 2007 from Cornell University; all in Electrical Engineering. From 1994 to 2000 he worked as an R&D engineer at the Ministry of Defense, and from 2000 to 2003, he was with the Algorithms Group at Millimetrix Broadband Networks, Israel. Since 2007 he is a postdoctoral researcher at the Department of Electrical Engineering at Stanford University.

Approximate time allocation for a three-hour tutorial:
Sec. 1: 35 min
Sec. 2: 35 min
Sec. 3: 20 min
Sec. 4: 35 min
Sec. 5: 20 min
Sec. 6: 20 min
Sec. 7: 15 min

References:

1. G. Kramer, I. Marić and R. Yates, “Cooperative Communications” Foundations and Trends in Networking, Hanover, MA: NOW Publishers Inc., vol. 1, no. 3-4, 2006
   This reference will be used for most parts given in the outline. Also, many references therein will be used. A small subset is given below.

Sample of references used for Section 2:

2. T. Cover and A. El Gamal, “Capacity Theorems for the Relay Channel” *IEEE Transactions on Information Theory, vol. 25, no. 5, Sept. 1979.*

3. G. Kramer. M. Gastpar and P. Gupta, “Cooperative Strategies and Capacity Theorems for Relay Networks” *IEEE Transactions on Information Theory, vol. 51, no. 9, Sept. 2005.*

4. F.M.J. Willems, “Informationtheoretical Results for the Discrete Memoryless Multiple Access Channels”. Ph.D. dissertation, Oct 1982.

5. J. N. Laneman, D. Tse and G. W. Wornell, “Distributed Space-time coded protocols for exploiting cooperative diversity in wireless networks”, *IEEE Transactions on Information Theory, vol. 51, no. 10, Oct . 2003.*

6. A. Nosratinia. T. E. Hunter and A. Hedayat, Cooperative Communications in Wireless Networks”, *IEE Comm. Magazine, Oct 2004.*

For more references for this section, please see Section 5 in Reference 1.

Sample of references used for Section 3:

7. Wei Wu, Sriram Vishwanath, Ari Arapostathis, “On the Capacity of Interference Channel with Degraded Message Sets”, *IEEE Trans. on Information Theory, Nov 2007.*

8. I. Maric, A. Goldsmith, G. Kramer and S. Shamai (Shitz), On the Capacity of Interference Channels with One Cooperating Transmitter, *European Transactions on Telecommunications, invited, to appear 2008.*

9. N. Devroye, P. Mitran,V. Tarokh ``Limits on Communication in a Cognitive Radio Channel,'' *IEEE Comm Magazine, Radio Comm. , June 2006.*

Sample of references used for Section 4:

10. F. Xue and P.R. Kumar, “Scaling Laws for Ad Hoc Wireless Networks: An Information Theoretic Approach” *NOW Publishers, 2006,* and references therein.

11. A. Ozgur, O. Leveque and D. Tse, “Hierarchical Cooperation achieves Optimal Capacity Scaling in Ad Hoc Networks” *IEEE Transactions on Information Theory, vol. 53, no. 10, Oct. 2007.*

Sample of references used for Section 5:

12. S. Katti. D. Katabi, W. Hu. H. Rahul and M. Medard, “The Importance of Being Opportunistic: Practical Network Coding for Wireless Environments, *Proceedings of Allerton Conference on Communication, Control and Computing, Sept. 2005.*