NSRC Industry Day, October 14, 2009

Overview of Research Activities WCAN

http://labs.ee.psu.edu/labs/wcan

Wireless Communications & Networking Laboratory

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Wireless Communications and Networking Laboratory : (since Jan.2002)

- Currently we have 11 members
  - 1 Postdoc, 8 PhD students, 1 MS student, 1 senior
- Currently we are supported by
  - National Science Foundation
    1. CyberTrust (2007)
    2. CNS-NeTS (2007)
    3. CAREER-CCF (2003)
  - DARPA-ITMANET (2006)
  - NEW! ARL: CTA in Network Science- Communication Networks Academic Research Center (2009)
- Recently completed: NSF-CNS, NSF-CCF, DARPA-CBMANET, TechCollaborative, PITA,Telcordia, Raytheon

What we do

- **Mission:** Understanding the performance limits and providing fundamental design principles of ***wireless communication networks.***
- **Our Main research theme** is **optimum design of "Nth" generation** wireless networks

High capacity, secure, reliable wireless communication

Research Areas

- Information Theory
- Wireless Communications
- Network Science

Current Focus

- **Security versus capacity trade-off** in multiuser systems; wireless ad hoc networks
- **Design and performance optimization** of relay networks of **agile cognitive radios**
- **Ultimate "Capacity" of MANETs**
- **Data delivery and security in quality-of-information-aware communication networks.**

Information Theoretic Security (NSF-TF/CCF 2005)

- Wireless security concerns currently handled by upper layers of the protocol stack → top-to-bottom approach.

- Can we design a secure wireless system from PHY up?
- Information theoretic security

✓ *Aim: Ultimate performance limits in the presence of adversaries/unauthorized nodes*

- Challenging design problems arise when we consider non-point-to-point communication systems with security threats, i.e., eavesdroppers and disrupters.
  - resource allocation for secure transmission AND maximum capacity
  - multiaccess/broadcast/relay channel, MIMO, CDMA

Secure Capacity of Wireless Networks (NSF-CT 2007)

✓ *Can we design a wireless network with 'perfect secrecy'?*

- Tool: Network Information Theory
- Complete immunity to eavesdropping nodes
- Challenging design problems arise when we consider non-point-to-point communication systems with security.
- Consider small networks first to gain insight to larger ad hoc networks.

New Design Insights

- We can design transmission strategies that *guarantee* confidentiality of transmitted information in the presence of computationally unbounded passive adversaries.
- These strategies are useful also in enabling cooperation with network nodes of lower security clearance.
- Interference when intentionally introduced to hurt adversaries is a good thing!
- Untrusted (but functionally trusted) entities can participate in the network and be helpful.
- Designing secure wireless (ad hoc, sensor) networks is possible at their foundation, i.e., PHY layer.
- This approach can replace or strengthen key-based approaches.

A New Information Theory for Mobile Ad Hoc Networks (ITMANET 2006)

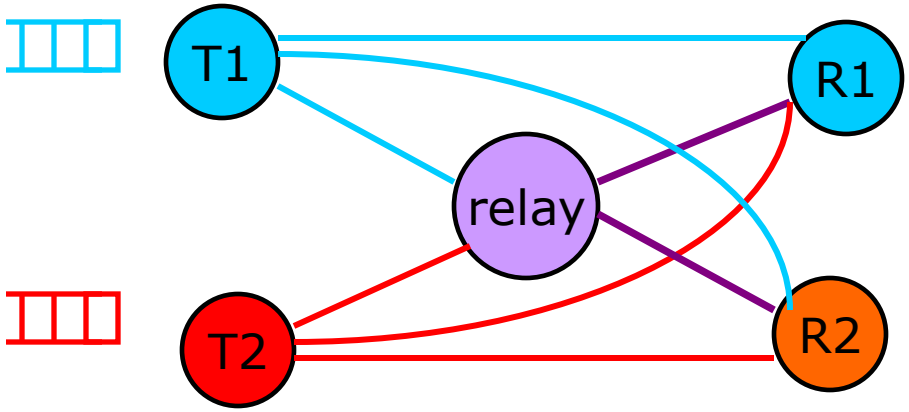
- With 12 colleagues from UT,UMN,ND,NW,USC,UC,MIT,Drexel
- Classical information theoretic tools are insufficient to address the ultimate performance limits of mobile ad hoc networks.
- Currently, there is no comprehensive theory to capture the dynamic nature of mobile ad hoc networks.
- Many rich sub-problems exist to address the statistical nature of the traffic, quantifying the impact of overhead and security.

✓ ***What is the ultimate capacity of a MANET?***

- This project IS an overarching theme of our research program.

New Design Insights

- New network building blocks considering interference and cooperation:



- New network control policies, rate allocation and scheduling, ensuring reliable communication and stable queues.
- New design techniques ensuring confidentiality of information.

Networks of the future (ARL: NS-CTA 2009)

- Network Science CTA Communication Networks Academic Research Center
- New network design paradigms
- Collaborative alliance with ARL and three other centers focusing on information networks, social and cognitive networks, and integration of all networks.
- Progress and design insights: see talks in future industry days ☺

Hybrid Wireless Networks (NSF-CNS 2006)

- A new network design paradigm where information is relayed through multiple wireless nodes that can operate with different standards.
  - Fusion of multiple communication standards
  - Synergistic combining to leverage advantages of different wireless networks (e.g., Wi-Fi plus HDR)
  - Throughput gain
  - Network reliability
  - Security

✓ *Hybrid Wireless Relay Network is the future wireless network*

✓ *Requires AGILE COGNITIVE radios*

Hybrid Wireless Networks

- Communication can be made more reliable if terminals can utilize multiple systems, possibly with different "standards".
- Theory points to benefits of "sharing" frequency resources between various standards ➔ practically feasible only with an open spectrum policy.
- Accurate spectrum sensing is needed to get the "most" out of this architecture. Cooperation between cognitive radios in sensing the spectrum is key to accomplish this goal.
- Complete system architecture, many challenges including trust issues and persuading the cognitive nodes to cooperate.
- Results, directions stem from the nature of the radio channel.

Cognition, Collaboration and Competition for Wireless Networks (NSF-CNS 2007)

- Primary wireless networks with licensed users.
- Overlay a "secondary" multi-hop wireless network of cognitive radios.
- Multiple cognitive nodes sense the same medium and would like to access ➔ Competition
- Collaboration between cognitive nodes helps improve chances of access/information transfer.
- Licensed users should not have to sacrifice their performance.

✓ *Can competition and collaboration co-exist?*

Multi-terminal MIMO NWs (NSF-CAREER 2003)

- Multiuser system with multiple antennas ➔ "Multiuser MIMO System"
  - Each user has multiple transmit antennas
  - Each user can only utilize its *resources (antennas)*
  - Users interfere with each other

Earlier Stages of the project focused on *performance optimization:* precoder-decoder design for all users (MIMO; CDMA-MIMO; designs with limited feedback, antenna selection).

Recent Progress

- Ad hoc networks where nodes employ or form virtual multiple antenna systems
- Bi-directional Communication (Two-way relaying)

More info

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