NSRC Industry Day, October 16, 2007

Overview of Research Activities WCAN

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

Wireless Communications & Networking Laboratory
WCAN@PSU

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

- Currently we have: 2 Visiting Professors, 6 PhD students
- Currently we are supported by
  - National Science Foundation
    1. CyberTrust (2007)
    2. CNS-NeTS (2007)
    3. CNS-NeTS (2006)
    4. TF- Comm.Research (2005)
    5. CAREER-TF-SignalProc.Sys. (2003)
  - DARPA
    1. ITMANET (2006)
    2. CBMANET (2006)
- Recently completed: NSF-CNS, TechCollaborative, PITA,Telcordia, Raytheon

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What we do

- **Mission:** Perform fundamental research on ***wireless communication network*** design

- Our Main research theme is optimum design of N^{th} generation wireless systems

High capacity, reliable, secure wireless communication

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Research Areas

- Rooted in Physical Layer of Wireless Systems
- Information theory
- Cross-layer design/Layerless design of Wireless Networks
- Multi-node, multi-antenna, relay assisted networks

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**
- **Overarching goal: Ultimate "Capacity" of MANET**

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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*

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Hybrid Wireless Networks

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- 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.

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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 can help improve chances of access.
- Licensed users should not have to sacrifice their performance.

✓ *Can competition and collaboration co-exist?*

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 intruders*

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

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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.

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A New **I**nformation **T**heory for **M**obile **A**d Hoc **Net**works **(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?***

- In essence, this project IS the overarching theme of our research program.

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Multiuser MIMO Systems (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

✓ *Performance optimization:* precoder-decoder design for all users *jointly.*

- narrowband MIMO channels
- CDMA-MIMO
- designs with limited feedback, e.g. antenna selection.

- Ad hoc networks where nodes employ or form virtual multiple antenna systems

Cross Layer Design for Network Coding **(CBMANET 2006)**

- CONCERTO is a multi-institution project (BAE Systems, CalTech, Cornell, MIT, Penn State (PI:T. La Porta), Stow Research, UIUC, UMass)
- Network coding is a new paradigm that allows packets to be combined in-network, as opposed to traditional forwarding (routing).

- The aim is to demonstrate that network coding along with careful cross layer design provides a significant performance improvement.

✓ *Interaction between physical layer, MAC and network layer via network coding*

More info

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