Overview of Research Activities

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- ***Wireless Communications and Networking Laboratory :***
  @ Penn State since January 2002

- **Members: 1 Post-doc, 8 students (4 PhD, 3 MS, 1 senior)**

- **Currently supported by**
  - **National Science Foundation (NSF-CAREER; CNS; CCF)**
  - **Pittsburgh Digital Green House (PDG)**
  - **Pennsylvania Infrastructure for Technology Alliance (PITA)**
  - **Networking and Security Research Center (NSRC)**

- **Industrial Partners: PDG: 7 member companies;**
  NSRC: Telcordia

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

- **Main research theme** is **optimum design of Nth generation** wireless systems

High capacity, **reliable**, **secure** wireless communication

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Research Areas

- Research concentrated on physical layer and its interaction with upper layers up to network layer for multiuser and multiantenna (MIMO) systems.
- Physical layer (PHY)
  - Current design focus:

    Jointly optimize all available resources for maximum multiuser system capacity;

    Security versus capacity trade-off in the multiuser setting
- Medium Access Control (MAC) layer
  - Current design focus:

    Improved MAC for dense low-power **RFID** networks
- Cross-layer approach (Joint PHY + MAC + routing)
  - Current design focus:

    Relay networks of agile radios

    Lifetime maximization for **sensor networks**

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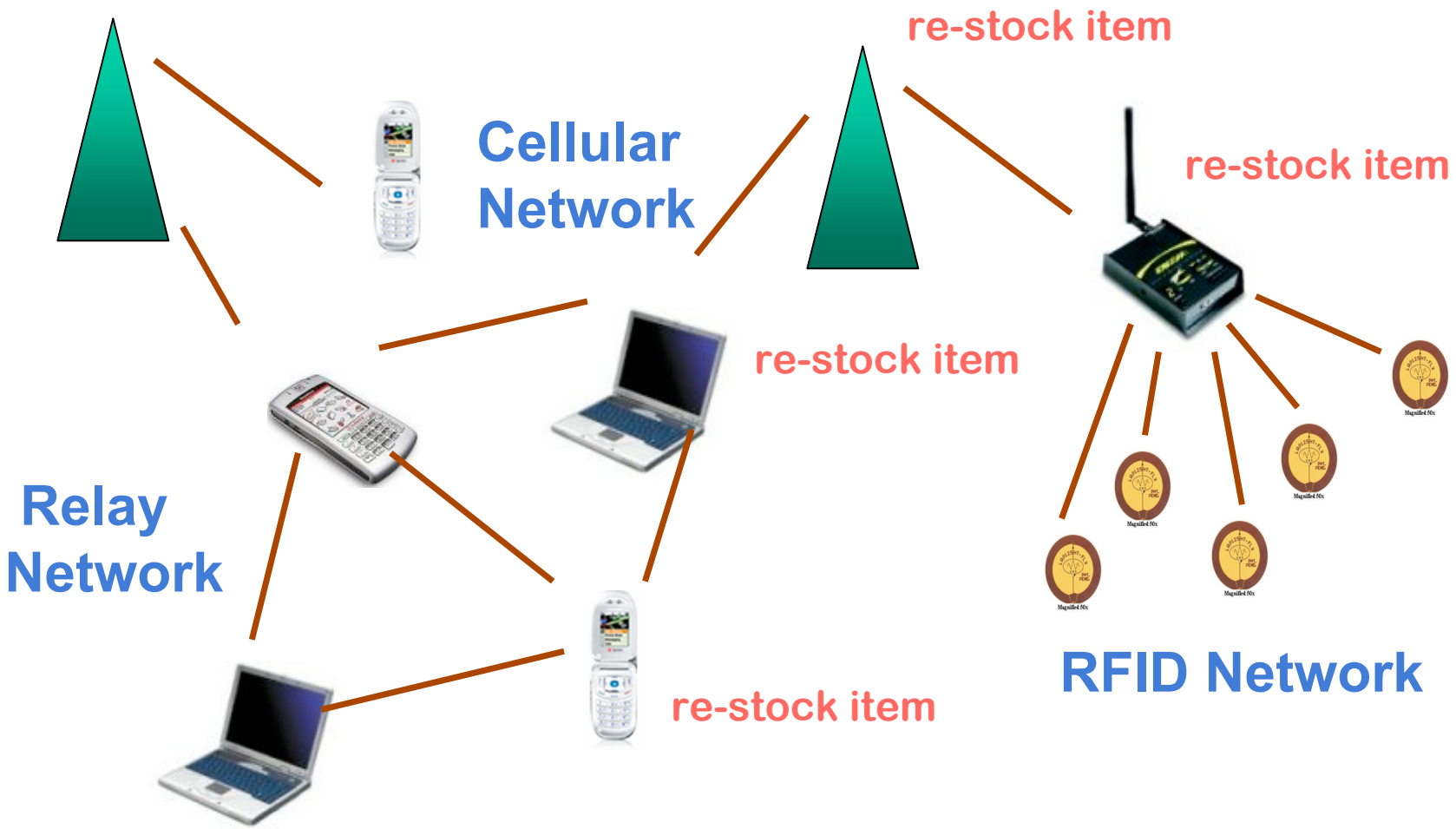
Research Vision: Wireless World



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Wireless Networks

- Future wireless networks will consist of cooperating nodes relaying traffic over several networks
- Radio frequency identifiers and other dense sensor networks, WLANS, cellular network will all have to co-exist and cooperate!
- Transceivers will be equipped with smart software radios that can change format (AGILE) in response to the current channel conditions (COGNITIVE)
- "Cognitive" radios will sense the medium to find the best way to transmit
- Multiple antennas and judicious choice of transmitters will increase capacity.

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Hybrid Wireless Networks (NSF-CNS)

- A new network design paradigm where information is relayed through multiple wireless nodes that possibly 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

- Power and bandwidth are limited wireless resources.
- Approach: from the information source, optimally allocate the transmitted power and bandwidth, between all available "standards".
- The optimum resource allocation provides higher capacity.
- Our results point to the merits of *sharing resources* between multiple communication standards in hybrid wireless networks.

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Multiuser MIMO Systems (NSF-CAREER)

- 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
  - Common receiver with multiple antennas

- Performance optimization: precoder-decoder design for all users *jointly.*
  - narrowband MIMO channels
  - CDMA-MIMO
  - designs with limited feedback, e.g. antenna selection.

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Secure Multiuser Systems (NSF-CCF)

- Wireless security concerns currently handled by upper layers of the protocol stack → top-to-bottom approach.
- Can we design a secure wireless network from PHY up?
- Physical layer security is more than simply employing spread spectrum!
- Challenging design problems arise when we consider non-point-to-point communication systems with security threats, i.e., eavesdroppers and (intelligent) jammers
  - determine secure capacity regions
  - resource allocation for secure transmission AND maximum capacity
  - multiaccess/broadcast/relay channel, MIMO, CDMA

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Cross Layer Design (PITA)

- **Ad-hoc wireless networks**
  - No central mechanism/infrastructure necessary
  - Interaction between physical layer, MAC, routing
  - **Key issue: We need distributed designs!**
- Enable concurrent transmissions for improved throughput?
- Utilize physical layer/resource allocation parameters for energy-efficient multi-hop routing.

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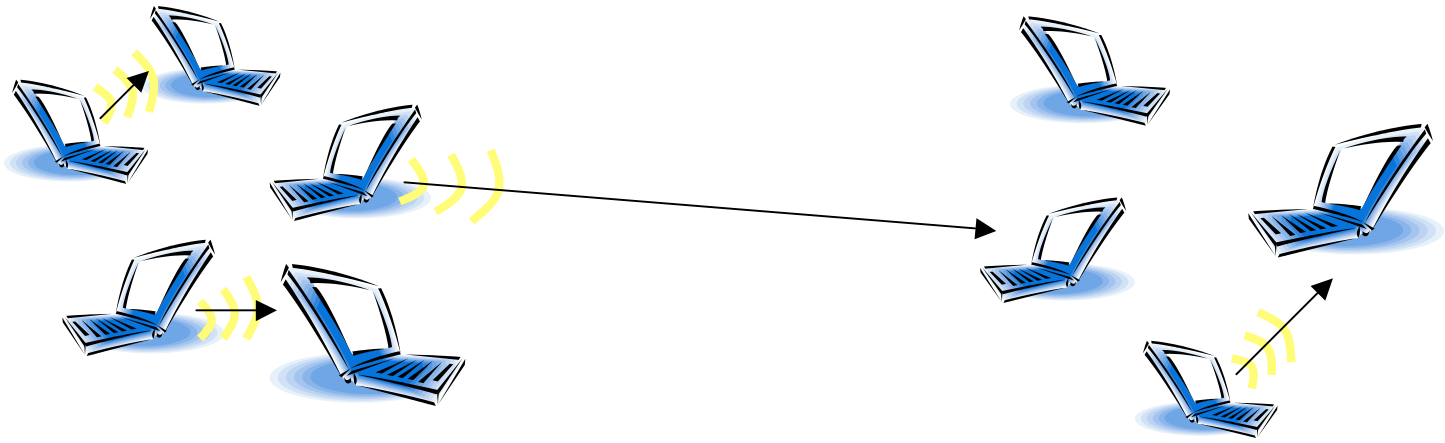
CDMA Ad Hoc Networks



- Using CDMA and distributed power control, concurrent transmissions can be supported to improve performance.
- Energy efficient routing policies must integrate physical/link layer conditions and allow for dynamic selection of forwarding nodes in clustered networks.
- MIMO ad hoc networks?

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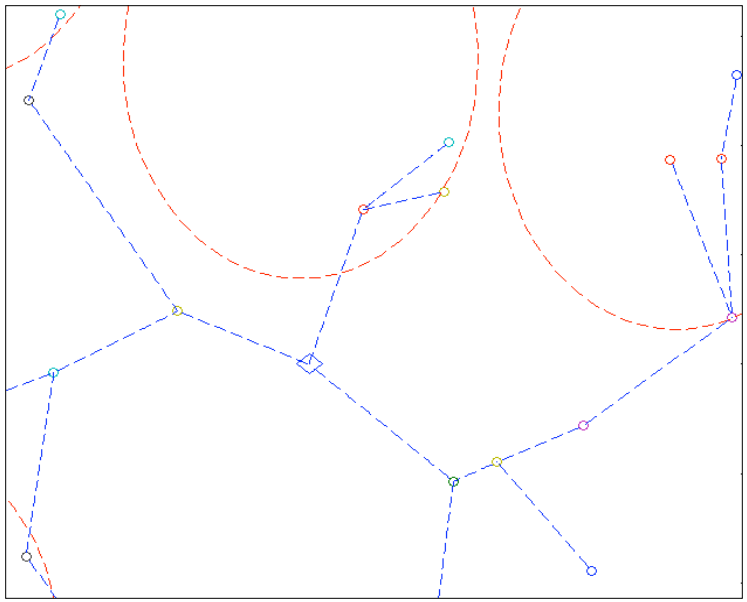
Lifetime Optimization for Sensor Networks (NSRC-Telcordia)

- Potential Applications: Intruder Detection, Ecological Monitoring…
- Goal: maximize the overall lifetime of the sensor network
- TDMA sensors; CDMA sensors
- Tiered network



Among the sensors reporting the same phenomenon have the ones with more remaining battery and better channels transmit → physical +MAC layer solution

RFID Networks (PDG)

- RFID tags are to be mounted on virtually everything !
- Driven by potential applications: identify individual components, inventory control, sensory information reports, security…
- Low power, short distance, dense wireless networks
- *Our research motivation: Total read time of current methods is too long when many tags need to be read*
- High level of collisions during multiple access → Design of novel multiple access schemes to identify tags in a timely manner (mobile tags to be read when they are in in the reader field)
- Our designs yield significant total delay reduction.

More info

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