Overview of Adaptive Networking
Research at WINLAB

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The Motivating Vision

- Public Switched Network (PSTN)
  - Custom Mobile Infrastructure (e.g. GSM, 3G)
  - BTS
  - MSC
  - BSC
  - CDMA, GSM or 3G radio access network

- Internet (IP-based → clean slate)
  - Mobile network overlays, etc.
  - Infostation cache
  - WLAN Hot-Spot
  - Ad-hoc network extension

- VOIP
  - Broadband Media cluster (e.g. UWB or MIMO)
  - Low-tier clusters (e.g. low power 802.11 sensor)

- WLAN
  - Access Point
  - WLAN (dual-mode)

- Today
- Future?
## Overview: Today and Adaptive Networks

1. Faculty Area Overviews
   - WINLAB research overviews in topics related to adaptive wireless networks: networking, physical layer, hardware platforms, and vehicular networks.

2. Keynote Speech and Demonstrations
   - Visions of where wireless research is heading, and where it **should not** head!
   - Walk through of WINLAB systems research and platforms

3. Physical Layer
   - What opportunities are there for cooperation at the lower layers for wireless communication?

4. Spectrum Awareness
   - How do we build the knowledge needed to take advantage of spectrum opportunities?

5. Adaptive Protocols
   - How can we adapt the network to cope with the challenges of distributing data and maintaining desirable levels of connectivity?
WINLAB Adaptive Networks

Requirements
- Applications need rapid response to dynamic conditions
- Networks should support multiple services with different QoS objectives
- Services should be secure and robust

Approaches
- Sharing of information across layers
- Sharing of measurements beyond local neighborhoods
- Tight and robust coupling between layers of the stack

Control Plane Architecture
Benefits:
- Decouples control and data plane
- More assured establishment of network services
- Easier to distribute critical network information
- Easier to secure critical network functions

WINLAB Initiatives
Global Control Plane (GCP):
- Cognitive radio networks
Cross Layer Ad Hoc Nets (CLAN):
- D-LSMA
- IRMA
- WARP-5
Secure MANETs (CARMEN):
- Four Ounces
- SEAR
Dynamic Spectrum: Problem Scope

- Dense deployment of wireless devices, both wide-area and short-range
- Proliferation of multiple radio technologies, e.g. 802.11a,b,g, UWB, 802.16, 4G, etc.
- How should spectrum allocation rules evolve to achieve high efficiency?
- Available options include:
  - Agile radios (interference avoidance)
  - Dynamic centralized allocation methods
  - Distributed spectrum coordination (etiquette)
  - Collaborative ad-hoc networks
**Dynamic Spectrum: Common Spectrum Coordination Channel (CSCC)**

- CSCC enables mutual observation between heterogeneous nodes to explicitly coordinate spectrum usage

- Exchange of CSCC messages by an extra narrow-band (low bit-rate) radio
- Periodically broadcast self-states to others
- Coordinate spectrum usage
Today:
We will explore several of the network algorithms that constitute the Common Algorithm Pool (CAP)
- DLSMA
- IRMA
- WARP-5
Ad Hoc Networks: Dual Radio Nodes with Global Control Plane (GCP)

- Separate control and data planes: reduces control overhead and enables contention-free global MAC/routing algorithms
- Can use a single low rate channel (e.g. 1 mbps 802.11b) for control
- Ad hoc network with global control currently being prototyped on ORBIT
**Framework of WINLAB Solutions**

- **Eliminate interference**
  - Interference-free link scheduling

- **Ensure QoS**
  - Use flow-based multiple queues to differentiate
  - Collect traffic flow load information
  - Bandwidth allocation/reservation

- **Robust control**
  - A separate control plane on control channel

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**D-LSMA Scheme**

- IP routing
- WFQs
- Scheduler
- Lower MAC
- 802.11 radio

**Internet**

**Multihop WLAN**

**Ethernet**

**IP routing**

**802.11 radio**
**D-LSMA: New MAC Architecture**

- **Old**
  - Same MAC scheme for all kinds of traffic in a single FIFO queue
- **New**
  - Classify packets based on different destination or traffic demands.
  - Scheduler: Choose a “good” schedule for buffered packets or flows and make reservation decisions.
- **Requires:**
  - Nodes have to discover the opportunities for link scheduling.
  - Build a schedule table by processing overheard RTS/CTS.
  - Reduce Contention
    - *Try to reserve multiple packets in one RTS/CTS handshake*
IRMA System Model

- Global control plane and data plane
  - All control signaling on a separate plane
  - Each node uses another radio interface over a dedicated control channel
  - Parameters of IRMA component in data plane is determined by control algorithms

- IRMA approach reduces signaling overhead as well as improves throughput performance

Protocol stacks in IRMA system
IRMA-MH vs. IRMA-BR

IRMA-BR algorithm chooses a detour path to route around possible congested areas by using available bandwidth measurement as metric.

Different routes used by (a) IRMA-MH and (b) IRMA-BR in a 6x6 grid for two vertical flows.
Warp-5: Wireless Adaptive Routing Protocol

- **Overview:**
  - Intended for the (CBMANET) CLAN architecture
  - Investigated by Brian Russel and Michael Littman in conjunction with WINLAB
  - Based on machine learning algorithms

- **Design philosophy:**
  - Routing protocols generally make decisions based on metrics that don't reflect quality of service objectives
  - Shortest route may not always be the fastest or best!
  - Cross-layer factors should be considered:
    - MAC/PHY level data: SNR, RSS, symbol error rate, bit error rate?
    - What about router congestion?

- **WARP-5:**
  - Distance vector, on-demand routing protocol for ad hoc networks
  - Time-based routing metric incorporates router congestion level and environmental noise/interference.
  - Routes around heavily-used routers and noisy links even if the route is longer.
  - Nodes learn estimated time-to-destination for all neighbors.
  - Protocol benefits present for both single channel and control-channel architectures

![Simulation Trial Runs](image)

**AODV-based Routing: Overload**

- **Simulation Trial Runs**
  - Total Packets Delivered
  - Simulation Trial Runs: 1, 2, 3, 4, 5, 6
  - AODV (1 radio)
  - AODV (Control Plane)
  - Warp-5 (1 radio)
  - Warp-5 (Control Plane)

Nodes 1, 2 and 3 all find the fastest route.