Overview of Mobile Networking Initiatives at WINLAB
Introduction: The Next Generation

Today → Future

- **Public Switched Network (PSTN)**
  - MSC
  - BSC
  - GGSN
  - Custom Mobile Infrastructure (e.g. GSM, 3G)

- **Internet (IP-based)**
  - Infostation cache
  - WLAN Access Point
  - WLAN Hot-Spot
  - VOIP (multi-mode)
  - Low-tier clusters (e.g. low power 802.11 sensor)
  - Ad-hoc network extension
  - Public Switched Network (PSTN)
  - BTS
  - CDMA, GSM or 3G radio access network
  - High-speed data & VOIP

- **Generic mobile infrastructure**
  - BTS
  - Infostation cache
  - WLAN Hot-Spot
  - Voice (legacy)
  - Ad-hoc network extension
  - Broadband Media cluster (e.g. UWB or MIMO)
  - Relay node
  - VOIP (multi-mode)
  - Low-tier clusters (e.g. low power 802.11 sensor)
Introduction: Future Protocol Architecture

2.5G/3G Services
- PSTN
- GSM/GPRS
- 2.5G/3G Radio

WLAN Services
- Mobile Service Middleware
- Ethernet
- 802.11 Radio

4G Services
- uniform service API (Internet+)

Unified IP-based mobile network
- Security
- QoS
- VPN
- Content Delivery

Generic Radio Access Network
- 3G/4G Radio
- WLAN radio
- WPAN/low-tier radio

Today’s Wireless Systems
- Radio-specific vertically integrated systems with complex interworking gateways

The Future
- Radio Independent modular system architecture for heterogeneous networks

WINLAB
WIRELESS INFORMATION NETWORK LABORATORY
Research Overview

Future Wireless Networks

Research Topics

- Multimedia Networking
- Ad Hoc Networking
- Sensor Networking
- Security and Privacy
- Testbeds and Validation
Wireless Multimedia Multicasting

Challenges
- Limited Bandwidth
- Time-varying, error-prone channels
- Receiver heterogeneity

Issue: What strategies can we employ to overcome the challenges of the wireless scenario?

Tools
- FEC
- ARQ
- Simulcast
- Layers

Proposed strategy being examined:
1. Employ multiple resolutions of video transmitted to different multicast groups
2. Clients subscribe to multicast groups based on their channel conditions
3. Centralized and distributed strategies for deciding appropriate group
Network Coding:
• Incorporate coding at intermediate network nodes
• Achieves higher throughput in a multicast network
• **Challenge:** Transmission rate is limited by the **minimum** capacity of all receivers

Multiple Description Network Coding:
• Multimedia MDC can ensure reliable media delivery
• MDs are transmitted at a rate of the **maximum** capacity of all receivers!
• Receivers with less capacity receive fewer descriptions
• **Graceful reduction in media quality**
Ad Hoc Networking
Protocols needed:

- Ad-hoc discovery (enhanced beacons, etc.)
- Ad-hoc MAC
- Ad-hoc network routing (extended metrics including energy)
- Handoff, QoS control, multicast (features)
Link scheduling to allow parallel transmissions, solves “exposed node” → useful for QoS on ad-hoc FN-FN infrastructure in hierarchical systems

Distributed scheduling algorithm (upper MAC), using 802.11-based lower MAC
Sensor Networking
Ad-Hoc Network: 3-Tier Sensor Net

- Self-organizing hierarchical ad-hoc wireless network (SOHAN) under consideration at WINLAB
  - **Tier 1**: low-tier mobile nodes, e.g. low-power sensors (MN)
  - **Tier 2**: forwarding nodes (FN) with multiple radio interfaces (UWB, WLAN, cellular…)
  - **Tier 3**: wired base stations and access points (BS or AP)
  - Research on new protocols for: ad-hoc discovery, MAC and routing
Sensor Energy Conservation via Adaptation

**Issue:** Network Lifetime

Question: How to determine the sleep interval?
- Tradeoff between energy conservation and responsiveness

**Current solution:**
- Use a fixed sleep interval that is small enough
- Energy conservation = sleep interval / wakeup time

**Proposed Solution:**
- Adaptive sleep interval

Active nodes: forwarding packets
- Backup nodes: Sleep + Wakeup
Wireless Security and Privacy
Authentication in Hierarchical Ad Hoc Sensor Networks

- Public key certificates are not suitable for flat ad hoc networks
  - To check certificate requires expensive public key operations

- Three tier architecture:
  - Varying levels of computational power within the sensor network
  - Sensors do not communicate with each other
  - Forwarding nodes are radio-relay

- TESLA Certificates
  - Alternative to PK certificates
  - Uses symmetric key cryptography
  - Delayed key disclosure

Authentication framework:
- Access points provide filter to application
- TESLA certificates provide efficient sensor node handoff
- **Weak and assured** data authentication provided
3G Multicast Security

- Keys must be shared by multicast group participants
- As users join and leave, keys must be changed
- 3GPP has proposed a new entity, the BMSC for managing broadcast and multicast services
- The BMSC can perform key management
Testbeds And Validation
Emergency Response Infostation

- Outdoor Infostations for Rapid Deployment
  - For first responders to set up wireless communications infrastructure at disaster site
  - Provides WLAN & sensor net services
  - Infostations for caching large files (maps, etc.)
  - Wireless backhaul link

- Prototype incorporates:
  - 802.11 MAC+ for Infostations pass-through mode
  - Content caching algorithm & software
  - Solar panels, antennas and embedded processor with WLAN card
  - Can be integrated with 802.11 ad-hoc sensors

WINLAB’s Emergency Infostation 2002
Medical Sensor with 802.11 WLAN

- First system-level MUSE prototype completed 11/03
  - New ECG interface board
  - CerfCube platform with 802.11b (off-the-shelf components)
  - WINLAB drivers & networking software

- Next steps
  - Make this prototype available to BioMed and UMDNJ collaborators
  - Integrate with ZnO devices
  - Continue work towards MUSE sensor SoP/SoC with low-power 802.11b
**ORBID Testbed**

- Open-access next-generation wireless network testbed being developed for NSF network research testbeds (NRT) program
- Large scale “radio grid emulator” for evaluating new concepts for future wireless networks, e.g. ad-hoc sensor nets, pervasive systems...
- Also, outdoor “field trial network” covering RU Busch & NB campuses for real-world application work

![Diagram of ORBIT Testbed](image-url)
ORBIT Testbed: Radio Grid