Mobile Networks Research: Area Review

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MobiNet Project Objectives

- WINLAB initiated a new core research area on next-gen mobile network arch & protocols in AY'01-'02

- Experimentally-based activity centered around the new “MobiNets” lab (in CORE529)

- Goals of research program
  - new concepts for next-gen (“4G”) wireless network protocols, applicable to future cellular, WLAN, sensor nets & pervasive computing
  - experimental evaluation of proposed protocols and related algorithms
  - system prototyping capabilities for proof-of-concept demos
  - advances in network software architecture & implementation
  - hands-on software prototyping experience for grad students
MobiNet Research Challenges

Several basic issues still need to be addressed for next generation wireless networks:

- Fast/reliable broadband radios (PHY/MAC) with QoS
  - ~100 Kbps \(\rightarrow\) 1-10 Mbps with adaptivity, link reliability & QoS

- Scaling of radio networks for ubiquitous wireless devices
  - architectures that support ~10's of devices/Sq-m, ~Gbps/Sq-Km...

- Integration of multiple radio technologies into single IP network
  - radio-independent generic mobile network, support for legacy protocols

- Faster and simpler standardization process, feature evolution
  - ...open-architecture networks, programmable features, etc.

- New networking modes, e.g. multicast, multihop & peer-to-peer
  - ...lower-cost infrastructure, networks that grow organically

- Truly “useful” mobile information services
  - ...beyond web browsing on phones/PDA’s, new portable devices
"4G" Network Evolution

Today's Wireless Systems

Radio-specific vertically integrated systems with complex intworking gateways

The Future

Radio Independent modular system architecture for heterogeneous networks
Potential “4G” Network Ideas

A few techniques for achieving the 4G design goals discussed earlier:

- **3G/WLAN Hot-Spots**
  - Use of WLAN in hot-spots for lower system cost, better end-user performance and more total capacity

- **Infostations**
  - Use of opportunistic “radio caches” for significant reduction in average cost per bit, facilitating qualitatively new mobile services

- **Self-organizing wireless access networks**
  - Ad-hoc wireless network protocols which support multihop and peer-to-peer service models, particularly for low-tier uses (in-home, sensors, etc.)

- **Content-based multicasting**
  - ...new network service paradigms for location- and person-aware information delivery to mobiles
MobiNets: Multimode Networks

Techniques for seamless service:
- Authentication, global roaming
- Security issues
- Dynamic handoff
- End-to-end QoS control
- Network management
- Service level agreements (SLA)

Protocol stacks

Unified Mgmt Layer

Multiple devices with various radio interfaces

5/02
Mobile user passes through Infostation in sec during which ~MB files are downloaded/uploaded
- Requires modifications to conventional WLAN MAC, incl fast synch, pre-authentication, etc. (...related to interworking discussed before)
- Motivates 2-tier arch with ~10m service zone (for high-speed data transfer) and ~50m access control zone (for sync, authentication, ..)

Transit time ~sec
Total transit time ~10sec
MobiNets: Infostations via 802.11 MAC

- 802.11a MAC can be used for Infostations service
  - Pre-authenticate user in low-bit rate mode (~50m range)
  - Mobile terminal waits for modem to reach max 54 Mbps (~10m range)
  - High priority access mode used for Infostations access

![Diagram of MobiNets: Infostations via 802.11 MAC](image)
MobiNets: Infostations Caching

- Infostation caches contain location-aware and user-specific data to be downloaded opportunistically
  - proactive caching involves various strategies including location context, user profiles, prediction of user location, etc.
  - content multicasting (with XML classification) potentially useful
MobiNets: Content Multicast

- New real-time, person- and location-aware information delivery paradigms need to be considered for 4G.
- Content multicasting based on XML investigated as possible option for delivering relevant info to mobiles.
MobiNets: Self-Organizing “4G” Network

- Hierarchical, self-organizing network concepts currently under consideration, based on:
  - 3 service tiers (cellular, WLAN, personal area)
  - BS’s, AP’s, FN’s (forwarding radio nodes), user devices
  - automatic discovery and power mgmt protocols
  - hierarchical, ad-hoc multihop routing and spatial MAC
MobiNets: Hierarchical Ad-Hoc Net

- Access Point (AP)
- Forwarding Node (FN)
- Sensor Node (SN)

Note: not a strict hierarchy

Ad-hoc FN/AP backbone

MAC cluster

First Tier SN

Second Tier (FN)

Third Tier (AP)

IP Network
**MobiNets:** Routing in Hierarchical Ad-Hoc Network

\[ \lambda = f (\text{Tx power, battery life, congestion, etc.}) \]

Need to consider PHY power, MAC and routing in an integrated way to optimize the system.

Ad-hoc & IP routing

MAC/Flooding

**WinLab**
MobiNets Lab: Experimental Network

- A flexible, open-architecture mobile network testbed has been set up during the ’01-’02 academic year
  - open-source Linux routers and AP’s (commercial hardware)
  - Linux and embedded OS forwarding and sensor nodes (custom)
  - radio link and global network monitoring/visualization tools
Each router node has 3 general purpose PCs:
- 1U form factor
- Single or dual CPU configuration with up to 1 GB of memory
- Quad 100 Mb/s Ethernet

Node can be used as:
- Router
- Server/Cache
- Access point
- Combination of above
MobiNets Lab: **Software platform**

**Main SW features:**
- **Open ⇔ Linux OS**
- By using packet filters minimizes driver development
- Multiple independent developers each with separate protocol stack
- Uses existing TCP/IP stack for control only
- Java based for ease of reuse and feature addition
MobiNets Lab: Sensor Module

Small, low-power platform with good hardware feature set sharing the same software platform with other node types

CerfBoard-SA:
- Intel® StrongARM™ 1110 microprocessor @ 206 MHz
- 16 MB ROM (FLASH)
- 32 MB RAM
- Compact Flash Interface
- 16 Digital I/O lines

Wireless Interface: 802.11b - Lynksys WCF11

OS: Linux 2.4.9

Typical power consumption: 450 mW
MobiNets Lab: Forwarding/AP node

Multi-purpose embedded platform with radio in/out, processing, routing and storage capabilities

**CompuLab 586CORE:**
- AMD ElanCS520 CPU - 133 MHz
- 32 MB ROM (FLASH)
- 32-64 MB RAM
- 2 x 100BaseTx Ethernet
- VGA/XGA, IDE - Hard Disk Interface, Dual PCMCIA Slot

**Wireless Interface:** 802.11b
- PRISM-2 PCMCIA Card with external antenna
- Cisco 350 with internal antenna

**OS:** Linux 2.4.17 kernel with both Infrastructure / Add-hoc mode support

**Typical power consumption:** 8 W
MobiNets Lab: RF Monitoring Node

Off-the-shelf Access Point running modified Linux OS with the wireless interface in RF Monitoring mode - used for spectrum monitoring and management support.

Eumitcom WL11000SA-N:
- AMD ELAN SC400 CPU
- 1 Megabyte ROM (FLASH)
- 4 Megabytes RAM
- NE2000 Ethernet Controller

Wireless Interface: 802.11b Generic PRISM-2 PCMCIA Card with external antenna

OS: Linux 2.4.17 kernel with Infrastructure mode support

Typical power consumption: 4.0 W
MobiNet Project Status & Future Work

- Initial goal of establishing the lab and getting control of router/AP/FN/SN platform software achieved
- Early research-level demo system of discovery in self-organizing network completed
- Infostations (with content multicast) demo for emergency/disaster recovery applications being developed for potential “tech transfer” uses

Future work during 2003:
- continue with discovery, power control, MAC and routing in hierarchical ad-hoc network prototype
- WLAN/2.5G interworking proof-of-concept prototype
- start examining security and information flow in pervasive computing scenarios
- initiate experiments on spectrum collaboration (..new ITR)
MobiNets Lab: Emergency Infostation Prototype

Forwarding node/Access Point with:
• 30 GB Hard Disk for caching
• High-gain directional antenna for backbone connectivity
• Omni-directional antenna for local coverage
• 3 hour battery
• Photovoltaic (solar) panels with the controller as a continuous power/battery charging source

Linux 2.4.17 kernel with:
• Infrastructure 802.11b support
• IP Bridging support
• JAVA Application support

Typical power consumption: 20 W