Introduction – cont.

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The Trend: Mobile Rules

Smartphone as a pool of sensors

List of Various Sensors

- WiFi (SO, LS, WI)
- Bluetooth (SO, EV, WI)
- GSM/GPRS/3G (LS, WI)
- Camera (SO)
- Accelerometer (MO)
- GPS (LS, MO)

- CPU (1 GHz)
- Storage (>2 GB)
- Software
- Energy
Things to Think About

• How to leverage these sensors
  – What type sensors?
  – What applications?
• How to leverage a crowd of smartphones
  – How to engage users?
• How to stay battery-friendly
  – What consume energy??
• How to protect privacy
  – What leads to information leakage?

Some Sample Mobile Projects


History of Wireless

Italian inventor Guglielmo Marconi’s 1901 transmission of a wireless signal from Ireland to Canada.
From Wired to Wireless

The Difference

Why?

- Radio wave propagation (like your voice)
  - Decreasing signal strength
    - Radio waves lose energy due to absorption or scattering
  - Multi-path fading; reflections from multiple objects; time varying due to mobility
  - Interference
    - Your signal is noise to others in the same frequency band
    - Broadcast nature
  - Network dynamics
    - Moving objects, weather
    - Node mobility

The Difference (2)
Understanding Interference

Impact of Interference

• More (unpredictable) packet error/loss
• Unreliable links
• Solutions
  – To handle low signal strength
    • Increasing power — results in higher interference
    • Better coding, modulation etc. — limited by capacity, very advanced already!
  – To handle interference
    • Coordination
      – Listen before talk
     – Use different spectrum frequencies
    • Hidden terminal problem

Medium Access

Why Control Medium Access

• Wireless channel is a shared medium
  – When conflict, interference disrupts communications
• Medium access control (MAC)
  – Avoid interference
  – Provide fairness
  – Utilize channel variations to improve throughput
Wireless Networks In the Last Decade

Overview of Various Networks

Cellular Networks

WPAN: Personal Area Networks

RFID

Bluetooth

Zigbee

Mesh

WLAN: Local Area Networks

WWAN: Wide Area Networks

Centralized Networks for Tight Control and Seamless Connectivity

Cellular Networks

MAC Categories

Wireless MAC Protocols

Centralized

Decentralized

Controlled access

Random Access

Channel reservation (token)

Cellular networks
base stations assign time slots/frequencies/codes to users
TDMA, FDMA, CDMA

1) 802.11, CSMA/CA, backoff if conflict
2) Ethernet, CSMA/CD

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Wireless Networks In the Last Decade

Cellular Networks
Cellular Network Overview

- Providing continuous, anywhere, anytime communication
- Geographic region divided into cells
- Frequencies/timeslots/codes reused at spatially-separated locations (shown as different colors)
- Operate in licensed spectrum (additional cost)
- Radio network controllers coordinate among base stations to connect users

Providing Continuous Connectivity

Cellular Network Evolution

Cellular Applications

- Smartphones merge computers, cameras, radio and communications.
- Conventional voice-only → email access → web browsing → rich media data applications
- High volume, delay sensitive, location-aware
Hot New Mobile Apps

- More exciting mobile applications into hyperspaces

The Datacom Version: WiMAX

- Worldwide Interoperability for Microwave Access
- **802.16d - DSL replacement**: A wireless alternative to cable and DSL
- **802.16e - Nomadic/Mobile**: Providing mobile broadband connectivity

LTE vs. WiMax

- Potential deployments: T-Mobile, Verizon, Cox Communications, Bell Mobility, Telus, Vodafone, France Telecom
- Commercial deployments: Sprint-Clearwire (Comcast, Time Warner Cable, Bright House Networks)

Hot Topic: Femtocell

- **Low-power wireless access points** that operate in licensed spectrum to connect standard mobile devices to a mobile operator’s network using the customer’s DSL or cable broadband connection.
  - about the size of the typical desktop Wi-Fi router - and can be deployed in a home or office.
**WiFi**

WLAN: Local Area Networks
Decentralized network architecture
Self-organizing, flexible, low cost
NOT designed for Mobility (Seamless Connectivity)
Multiple standards Using Unlicensed Bands

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**WiFi Everywhere**

- WiFi at Starbucks, Borders, MacDonald's, Airports, Trains, Airplanes, Parks, Shopping Malls
- WiFi enabled memory cards, VoIP phones etc.

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**Existing WiFi Devices as the path to Internet**

- **Mesh networks**: WiFi mesh nodes scattered over the coverage area; interconnected into a mesh using the same WiFi technology as do the end-user clients in connecting to the mesh nodes themselves.

- No more costly backbone
  - DSL, Cable etc.

- Workaround, multihop backhaul
- Self-organize, low cost
- Community networks

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**The Crash**

- In 2007, Big City municipal WiFi projects in New York City, Los Angeles, Chicago, Houston, Atlanta, San Francisco, Portland and New Orleans all hit the skids when the limitations of WiFi became apparent.

  The cost of delivering WiFi everywhere was more expensive than WiMAX on a square mile basis, and less reliable.

- Require 40 nodes per sq mile rather than 25 or so
- Poor indoor penetration ➔ Need a $150 WiFi repeater in the home.
- The very success of WiFi created self-interference, reducing range
- Neither the subscription nor ad revenue model penciled out when all the costs were added up:
2009 Community WiFi Reborn

- Theories that municipal Wi-Fi would kill the telcos and cellular business proved wrong.
- Cellular carriers are experiencing a 100x or more increase in 3G data usage (thanks to iPhone), so users are suffering
  - Lose customers or Offload data traffic to another network (WiFi)
- Cellular carriers are rolling out Citywide WiFi networks for a fraction of the cost of 4G networks
  - Only Free for Cellular Users.
  - Better QoS control
  - Better security

Factors that Make WiFi Cheap

- No QoS guarantee in mind (at least initially)
- No Mobility in mind
- Unlicensed spectrum (no spectrum cost)
- But.....

Hot Topics: White Spaces

- Finding New Unlicensed Spectrum
  White spaces are unused television frequencies. They have been freed up by the shift to DTV. Analog television required broadcasters to leave blank television channels between nearby transmitters to prevent cross channel interference. With DTV, most of them are no longer needed. A study estimated that the unlicensed white spaces could be worth more than $100 billion over the next 15 years

It is Already Here!

- For the first time in the U.S., “white spaces” are being used to wirelessly deliver high-speed Internet connectivity.
- Microsoft, Dell, and Spectrum Bridge helped design and deploy a wireless TV white spaces network to distribute broadband Internet connectivity in Claudville, Virginia, under an experimental license granted by the FCC.
- Whether it will prove effective for municipal broadband wireless is to be determined
Hot Topic: WiFi Vehicular Networks

WiFi Summary

- Low-cost, decentralized networks
- Unlicensed spectrum for easy deployment
- Now face heavy interference
- Hot topics:
  - 3G offload
  - Whitespace (finding new high-quality spectrum)
  - Beamforming/Smart Antenna (nullify interference)
  - Vehicular networks (Wifi cars)