CS 525M – Mobile and Ubiquitous Computing Seminar

Emmanuel Agu

A Little about me

- Faculty in WPI CS
- Research interests include graphics, mobile computing/wireless and mobile graphics
- How did I get into wireless?
  - 3 years in wireless LAN lab (*pre 802.11*)
  - Worked on designing, simulating, implementing wireless protocols
  - We actually built working wireless LAN testbed
- Computer Systems/Electrical/Computer Science background

About this class (Administrivia)

- **Class goal:** to give overview, insight into issues in mobile and ubiquitous computing
- Full course name: *Mobile and Ubiquitous Computing*
- Will meet for 14 weeks, now scheduled for 15 wks
- 1-week break: either during undergrad term break or at the end (TBD)
- Seminar class: I will present, **YOU** will present selected papers
- Gain big picture through focussed discussions
- Check for papers on course website: http://www.cs.wpi.edu/~emmanuel/courses/mobile_computing/
- This area combines lots of other areas: (networking, OS, software, etc): No one has all the background!!

Administrivia: Papers

- Weeks 1 and 2: I will present
- Weeks 3 – 13:
  - First, I will present background material, motivate topic, from **Background Papers** for week
  - Two student presentations from **Required Papers** section for the week
- Each presentation should last about 30 minutes with about 20 minutes of discussion
- 5-min break between talks

Formal Requirements

- *What do you have to do to get a grade?*
- Come to class
- Seminar = Discuss!! Discuss!! Discuss!!
- Select and present about 2 papers
- Do term project, 4-phases
  - Decide project area (3 wks)
  - Propose project (5 wks)
  - Implement, evaluate, experiment (5 wks)
  - Present results (in week 14) (1 wk)
- Grading policy: presentations 50%, class participation 10%, final project 40%

Student Introductions!

- Please introduce yourself
  - Name
  - Status: grad/undergrad, year
  - Relevant background: e.g. coal miner ☺
  - What you would like to get out of this class?
    - Understanding of a hot field
    - Just a class for masters degree
    - Research interests/publications
    - My spouse told me to ☺

Next… Overview

- Today, quick overview of topics/issues
- Fire-hose section designed to excite you (or discourage you)
- More questions, problems than solutions
- ALL topics will be covered in more detail later
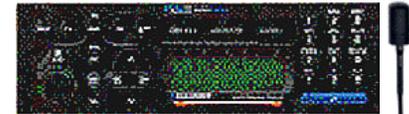- Most students will only understand part of the topics in today's overview

Mobile computing

- Mark Weiser, Xerox PARC CTO
- 1991, articulated vision for ubiquitous mobile computing, outlined issues
- **Vision:** *environment saturated with computing and communication capabilities, with humans gracefully integrated*
- Invisible hardware/software that assist human
- Weiser's vision was ahead of its time and available hardware and software
- For example, voice recognition was not available then
- Today, envisioned hardware and software is available

Mobile computing

- Applications:
  - Vertical: vehicle dispatching (trucks), package tracking (UPS), point of sale
  - Horizontal: collaborative computing, universal data/internet access, messaging systems, streaming multimedia, video conferencing, mobile games, interactive maps
- Mobile devices:
  - PDAs, laptops, cell phones, watches, etc
  - Limited hardware due to regulations, budget constraints (CPU, memory, disk space, battery, screen size)
- Wireless network connection: 802.11, cellular network (GSM, GPRS), satellite (VSAT)
- Desirable attributes: convenience, flexibility, portability
- Favorable trends: more powerful devices, faster digital networks (voice, data, multimedia)
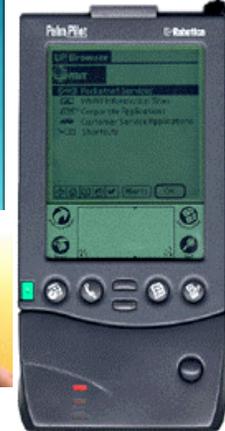
Mobile Devices

Car Stereo-Phone

Ericsson MC 12

Subscriber Identification
Module (SIM)

CDPD
Modem

From:Hanako_Sato
Subj:Happy holida
ys
We wish everyone
a pleasant nation
al holiday next M

Portable, mobile & ubiquitous computing

- Mobile users require different levels of connectivity
- Definitions:
  - *Distributed computing:* system is physically distributed. User can access system/network from various points. E.g. Unix, WWW. (huge 70's revolution)
  - *Portable (nomadic) computing:* user intermittently changes point of attachment, disrupts or shuts down network activities
  - *Mobile computing:* continuous access, automatic reconnection
  - *Ubiquitous (or pervasive) computing:* computing environment including sensors, cameras and integrated active elements
- This class concerned with last 3 (nomadic, mobile and ubiquitous)

Distributed Computing

- **_Distributed computing example:_** You, logging in and web surfing from different terminals on campus. Each web page consists of hypertext, pictures, movies and elements anywhere on the internet.

- **Note:** network is fixed, YOU move

- Issues:
  – Remote communication (RPC),
  – Fault tolerance,
  – Availability (mirrored servers, etc)
  – Caching (for performance)
  – Distributed file systems (e.g. Network File System (NFS)
  – Security (Password control, authentication, encryption)

Nomadic Computing

- **_Portable (nomadic) computing example:_** I own a laptop. Plugs into my home network, sit on couch, surf web while watching MTV. In the morning, wake up, un-plug, shut down, bring laptop to school, plug into WPI network, start up!
- **Note:** Network is fixed, except for your device and its point of attachment. You take your device with you!!
- Issues:
  - File/data pre-fetching
  - Caching (to simulate availability)
  - Optimistic update policies
  - Re-integration and consistency models
  - Operation queuing (e.g. emails while disconnected)
  - Mobile databases (fragments, objects may shared)
  - Resource discovery (closest printer while at home is not closest printer while at WPI)
- Note: much of the adaptation in **"middleware"** layer

Mobile/Ubiquitous Computing Examples

- *Mobile computing:* Sarah owns SPRINT PCS phone with web access, voice and short messaging. Remains connected while she drives from Worcester, Massachusetts to Compton, California
- **Note:** Network topology changes, because YOU and mobile users move. Network deals with changing node location
- Issues
  - Mobile networking (mobile IP, TCP performance)
  - Mobile information access (bandwidth adaptive)
  - System-level energy savings (variable CPU speed, hard disk spin-down, voltage scaling)
  - Adaptive applications: (transcoding proxies, adaptive resource management)
  - Location sensing (Use 802.11 signal strength to determine location)
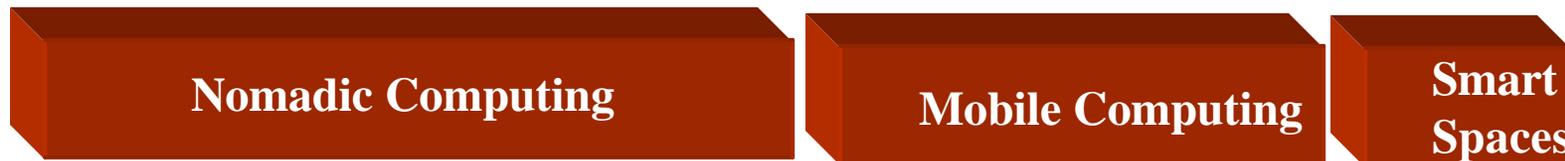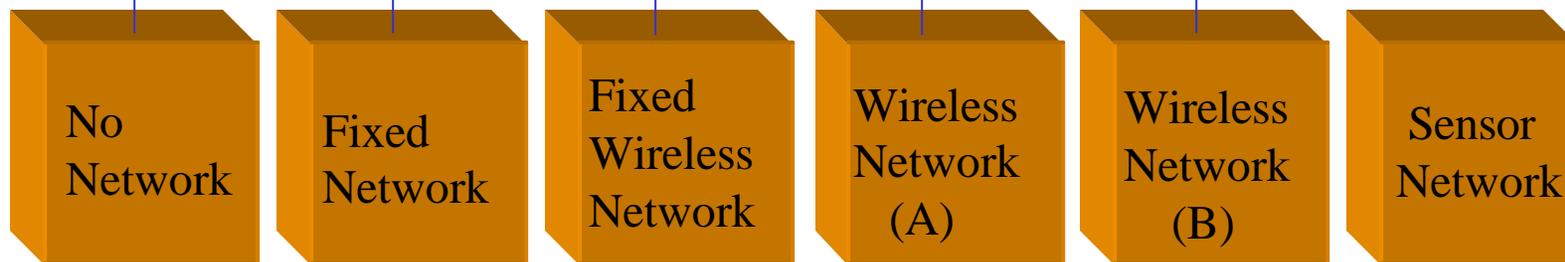 - Resource discovery (e.g. print to closest printer)

Mobile/Ubiquitous Computing Examples

- **_Ubiquitous computing:_** John is leaving home to go and meet his friends. While passing the fridge, the fridge sends a message to his shoe that milk is almost finished. When John is passing grocery store, shoe sends message to glasses which displays "BUY milk" message. John buys milk, goes home.
- **Note:** You may need an Aspirin for this one!!
- Issues:
  - Sensor design (miniaturization, low cost)
  - Smart spaces
  - Invisibility (room million sensors, minimal user distraction)
  - Localized scalability (more distant, less communication)
  - Uneven conditioning
  - Context-awareness (assist user based on her current situation)
  - Cyber-foraging (servers augment mobile device)
  - Self-configuring networks

Summary/Relationships

- Systems perspective: nomadic and mobile are **reactive**, ubiquitous is **proactive**

- Distributed systems + mobile computing research issues = mobile computing

- Mobile computing + pervasive computing issues = pervasive computing

- In this class, first part will be mobile/nomadic computing, then ubiquitous computing part

Portable, Mobile & Ubiquitous Computing

No Network	Fixed Network	Fixed Wireless Network	Wireless Network (A)	Wireless Network (B)	Sensor Network

Nomadic Computing **Mobile Computing** **Smart Spaces**

Ubiquitous Computing

Mobile Computing Challenges

- Mobile Computing Issues:
  - Mobile device issues
  - Wireless networking issues

- Mobile device issues
  - Short battery lifetime (Lithium ion battery: 5 hrs max)
  - Limited hardware (display, memory, disk space, etc). E.g. wireless web designers use multiple large screens to design pages for cell phone PDA
  - Prone to theft and destruction
  - Unavailable (frequently powered-off)
  - Few standards (hardware, architecture, etc)

Network Backbones

- Developing countries have 4 main wide area telecommunications networks (or backbones)
  - Internet
  - Telephone
  - Cable television
  - Cellular phone
- Most of these are hierarchical: divided into **backbone** and **local loop**
- Internet is main computing backbone
- Major companies/universities directly on Internet
- Small companies/residential use other local loops to access internet
- Result: huge trend towards making making other local loops digital, carry data (e.g. ADSL, cable modem, wireless local loop)

Wireless Networks Types

- **Cellular Network:** Wide area wireless network operated by Sprint, Verizon, AT&T, etc. 1G (analog), 2G today's network, 3G coming, 4G (in some labs)

- **Infrastructure networks:** wired backbone (Internet), wireless last hop. E.g WPI wireless LAN

- **Ad hoc networks:** all wireless, no backbone, no order known in advance. E.g. few deployed examples.. .futuristic

- **Sensor networks:** self-organizing network of large numbers of cooperating sensors deployed inside phenomenon. E.g. even more futuristic. Many research projects

Wireless Networking Challenges

- Wireless networking issues
  - Wireless spectrum scarcity => low bandwidth, asymmetric
  - Wireless channel characteristics: multipath fading, noise, echos, etc)
  - Variable and unpredictable network quality (high bit error rates (10^{-3}), varied user locations)
  - Uncontrolled cell population
  - Different points of attachment to network
  - Less secure and less robust (e.g. signal leakage)
  - Heterogeneous hosts and network links
  - Frequent network disconnections (cell phone)
  - Tough to guarantee Quality of Service (QoS)

Adopt 5-layer Networking Model

- 5 layers (not 7 OSI):
  - application (with middleware) e.g. email
  - Transport: end-to-end ACK
  - Network: routing
  - data link: link-to-link ACK
  - physical layer: wireless
- CS approach
  - Start with applications
  - Initially only minimalist PHY abstraction
  - Later, we will talk about PHY in detail
    (modulation, antenna diversity,

  encoding, radio propagation models, etc)

| Application |
| Transport |
| Network |
| Data Link |
| Physical |

Wireless Application

- Mobile data (Broadcast disks):
  - Wireless channel is broadcast in nature
  - 1 person talks, everyone hears
  - Take advantage of this for streaming data (e.g. stock quotes)
  - Problem: what streaming pattern is optimal for multiple recepients
- Wireless/mobile standards
  - Wireless web: iMode, Wireless Access Protocol (WAP)
  - Wireless messaging: cheaper, new messaging standards
  - MPEG-4 has wireless features in encoding
  - Scalable Vector Graphics (SVG): bit-mapped to vector graphics move
 - J2ME: Reduce Java Virtual Machine (JVM) to bare essentials

Physical Layer

- Too many gadgets want wireless spectrum: garage openers, radio stations, WLAN, etc
- FCC allocates wireless spectrum: some licensed, some unlicensed. E.g Radio 94.5FM licensed
- FCC solves demand problems by lumping many users into ISM bands (900MHz, 2.4GHz, 5.5GHz)
- Each country decides its ISM bands. Only 2.4GHz worldwide
- WLANs use ISM bands
- Interference between devices can be a problem: use spread spectrum
- FCC previously mandated spread spectrum in ISM bands, dropped this in 2002
- Result? My home phone now interferes with WLAN
- Speed increases 802.11b-g are mostly from PHY layer advances: e.g. more symbols per n bits

MAC Sub-Layer Issues

- Medium Access Control (MAC) layer is first protocol layer above unreliable wireless medium
- Need to perform medium access function while compensating for wireless channel
- PHY layer effects on MAC:
  - Channel: slow, asymmetric, time-varying (fading)
  - Errors: random and burst
  - Location-dependent carrier sensing
    - Hidden Terminal
    - Exposed Terminal
    - Capture effect
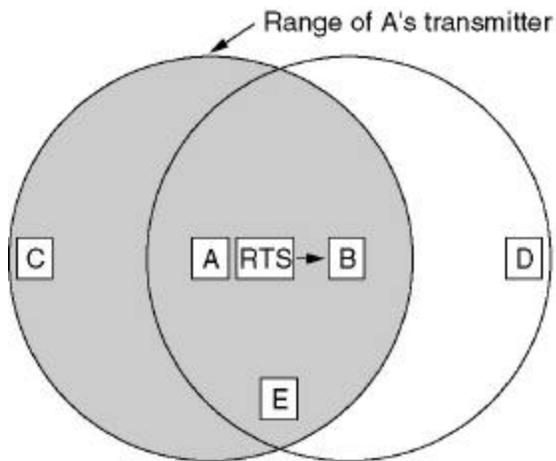
Hidden/Exposed Terminal

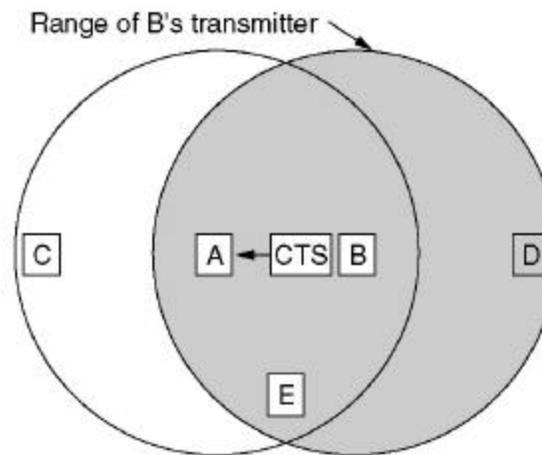Radio range
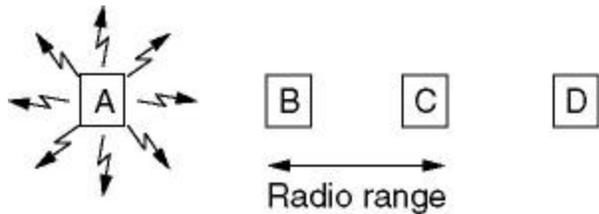
(a)
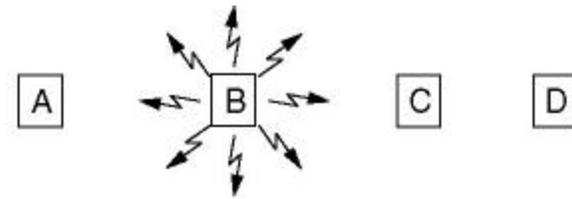
(b)

(a) Hidden station problem.

(b) Exposed station problem.

Range of A's transmitter

Range of B's transmitter

(a)

(b)

RTS-CTS handshake before starting transmission solves hidden terminal, called **Collision Avoidance**

MAC Sub-Layer

- Why not use old MAC standards like Ethernet?
  - Ethernet **(CSMA/CD)**detects collision by measuring voltage levels. Wireless MAC cannot rely on this because of presence of high atmospheric noise
  - Token-based protocols are bad idea because token easily lost
  - Centralized protocols like polling mean arbiter is always on, preferably wired, one point of failure (battery, jamming, etc)

802.11 MAC Sub-Layer

- What techniques are used in wireless MACs?
- 2 main standards: IEEE 802.11, or European HiperLAN-2
- 802.11:
  - Infrastructure: uses Access Points (AP), or ad hoc
  - Distributed MAC protocol (CSMA/CA)
  - RTS-CTS-DATA-ACK packet sequence (ACKs each pkt)
  - Retransmissions: give up early (7 retries instead of 10 in Ethernet) because retries do not help jamming.
  - Exponential backoff algorithm like Ethernet
  - Time synchronization: AP periodically broadcasts time
  - Priority scheme: different wait periods for different types of packets, traffic called **Interframe Space (IFS).** E.g. ongoing conversation (CTS, DATA, fragment) < new multimedia traffic < non-multimedia new traffic

Network Layer Issues

- Routing is key issue in network layer
- Original IPv4 did not consider mobile nodes
- Would like mobile nodes to roam without service disruption
- Mobile IP (RFC 2002) fixes IP problems with mobile nodes in infrastructure networks including:
  - Addressing
  - Security
  - Route inefficiencies
- Addressing:
  - Each IP address associated with fixed network location. E.g. 130.215.36.150 is *ccc.wpi.edu*.
  - What if mobile user with IP address 130.215.36.90 took laptop to Apple conference in California?

Mobile IP

- Mobile IP assigns mobile host 2 addresses: **fixed home address** and **care-of-address** which changes with new networks

- Analogy? PO or friend forwards mail

- TCP connections needs same *(src IP, src port, dest IP, dest port)*, uses **fixed home address**

- IP needs IP of new mobile host network, uses **care-of-address**

- *Home agent* in home network

    a. receives packets addressed to *fixed home address,*

    b. encapsulates it in new packet with care-of-address and

    c. forwards it to *foreign network (tunneling)*

- Mobile host does **reverse encapsulation** in foreign network so that its TCP connections still work well

- Mobile host has to *register* new care-of-address anytime it moves

Ad Hoc Routing

- Fixed networks use shortest path routing metric
- Shortest path has different meaning in ad hoc networks. Why?
    - Nodes are constantly moving
    - Link quality and node availability vary quickly
    - In general, highly mobile node should be avoided as intermediate node
- New ad hoc routing metrics: link delay, signal strength, power life, route relaying load
- Ad hoc routing types:
    - Table-driven: maintain one tables per metric
    - Source-initiated Demand-based: permutate all routes
    - Associativity-based: combine metrics using weighting
- Research issues: QoS, power, multicast awareness

Transport Layer Issues

- Transport layer concerned with end-to-end data transmission
- TCP assumes all timeouts caused by congestion
- Why? Before wireless congestion more likely
- Philosophically, congestion action is to **decrease transmission**, wait longer (increase congestion window)
- Wireless errors, MAC collisions require opposite = **increase transmission**
- TCP will work unmodified for wireless, however huge **performance** penalties

Transport Layer

- Wireless transport layer strategies:
  - Link layer strategies: FEC, base station agent that caches quickly retransmits packets, inform TCP of wireless loss
  - Split connections: 1 TCP connection for wireless (short RTT timer), 1 TCP for wired (longer RTT timer), violates semantics
  - Receiver/Sender discrimination: try to infer congestion/wireless loss from packet inter-arrival time pattern

Wireless Security

- Wireless signals leak beyond building confines
- Mobile devices designed to be carried around=> more prone to theft or misplacement
- Mobility: tracking perpetuators is hard
- Security standards like Wireless Encryption Protocol (WEP) have significant demonstrated flaws
- Anderson: over 90% of security breaches caused by lapses in physical security:
- **Example:** drunk employee at bar with laptop

Wireless Security Areas

- Cryptography (low power, strong enough, etc)

- Enforcing confidentiality (preventing traffic analysis, etc)

- Key Management

- Authentication mechanisms

- Intrusion detection

- Tamper-proof hardware

- Protocol vulnerabilities:

  - **Rogue APs:** Attacker inserts access point, hijacks mobile nodes

  - **Jamming:** ISM bands prone to that, microwaves, etc

  - **Induce congestions, collisions:** Induce collisions, congestion, disobey protocol. Delay bad for multimedia

  - **Exhaustion:** Keep sending packets to wireless node, prevent sleep modes, drain battery, DoS

  - **Packet header manipulation:** e.g sequence/ACK Nos.

Ubiquitous Computing

- Mobile computing deals mostly with passive network components
- Human simply provided universal, seamless network connectivity
- Human does all the work, initiates all network traffic!!
- Ubiquitous computing introduces collection of specialized assistants to assist human in simple defined tasks
- Networked array of active elements, sensors, software agents, artificial intelligence
- Ubiquitous computing builds on *distributed systems* and *mobile computing*

Sensors and Smart Spaces

- Sense what?
  - *Human:* motion, mood, identity, gesture
  - *Environmental:* temperature, sound, light/vision, humidity
  - Location
- Environmental is easy, simply integrate
- Human is a little harder
  - **Where:** location (easiest):
  - **Who:** Identification
  - **How:** (Mood) happy, sad, bored (gesture recognition)
  - **What:** eating, cooking (meta task)
  - **Why:** reason for actions (extremely hard!)
  - **Note:** Human-related (gesture, mood, etc) easier with cameras than sensors
- Work in smart office, smart kindergarten, smart office, etc

Sensor Node

- 1000s per room
- low power, multifunctional, low cost ($1 per sensor?)
- Sensing, data processing, communication
- Senses specific phenomenon, minimal processing and sends results to a sink node
- Small OS, programmable
- Also: new RFID tag push

(courtesy of MANTIS project, U. of Colorado)

Sensor Networking

- Sensor network is similar to ad hoc network with few differences:
    - Many more network nodes
    - Sensor nodes are densely deployed
    - Deployment? Throw a bunch into phenomenon
    - Sensors are prone to failure
    - Many nodes => topology change likely
    - Sensor nodes use broadcast, ad hoc networks tend to be point-to-point
    - Sensor nodes more limited power, CPU, etc
    - Globally distinct ID (IP address) not feasible because of number of nodes

Sensor Protocol Stack

- Sensor network impacts different layers
- Some issues such as power management permeate multiple layers
- Sensor PHY layer
  - similar to ad hoc network
  - sensor hardware design getting more mature
- Sensor MAC layer
  - Still perform media access
  - Add self-organizing: Initially (throwing) and if nodes go down
  - Even better resource management (power, bandwidth)

Sensor Network Layer

- Distinguish between your traffic and other (routing) traffic
- If you are already committed to helping, good sensor node may drop its own packets!!
- Multiple optimal routes:
  - Maximum power available route
  - Minimum energy route
  - Minimum hop route, etc
- Sensor router may do minimal processing to aggregate packets from multiple nodes
- Attribute-based naming instead of IP address. E.g. "***all nodes in region with temp over 70 degrees***" better than temp reading or IP address

Sensor Transport Layer

- Almost no work on sensor transport layer
- Split connections may be promising
- ACKs too expensive for sensor network
- Attribute-based naming replaces IP addresses
- Dynamic/self set-up, currently human configures all network nodes

Homework

- Go home
- Scan papers for each week
- Decide and order top 5 areas (weeks) that you are interested in
- Next week, we will sign up for talks
- Procedure: we will pass around paper, simply sign