CS 525W: Mobile ***Ubiquitous*** Computing and Wireless Networking

Emmanuel Agu

A Little about me

- Faculty in WPI Computer Science
- ***Research interests:*** graphics, mobile computing/wireless and mobile graphics
- How did I get into mobile computing + wireless?
  - 3 years in wireless LAN lab (*pre 802.11*)
  - Designed, simulated, implemented wireless protocols
  - Group built working wireless LAN testbed (*pre 802.11*)
- Computer Systems/Electrical/Computer Science background
  - Hardware + software

About this class (Administrivia)

- **Class goal:** provide overview, insight into hot topics, ideas and issues in mobile ubiquitous computing and wireless networking
- Full course name: ***Mobile Ubiquitous Computing and Wireless Networking***
- Meet for 14 weeks, break on March 8 (term break)
- Seminar style: I will present, **YOU** will present papers
- See big picture through focussed discussions
- Check for papers on course website: http://web.cs.wpi.edu/~emmanuel/courses/cs525m/S11/
- **Projects:** 1 or 2 assigned, 1 big final project
- This area combines lots of other areas: (networking, OS, software, machine learning, etc): Most people don't have all the background!!
  - Projects: Make sure your team has requisite skills

Administrivia: Papers

- ***Weeks 1 and 2:*** I will present
- ***Weeks 2 – 12: You*** will present + I will present
  - I will present background material on the week's topic
  - 3 student presentations from **Required Papers** for the week
- Student presentations: ~30 mins + ~10 mins discussion
- 15-min break halfway through each day

Formal Requirements

- ***What do you have to do to get a grade?***
- Seminar: Come to class + Discuss!! Discuss!! Discuss!!
- Present 2 or 3 papers
- Email me 1-page summaries (in ASCII text) for weekly papers
- Do assigned project(s)
- Do term project: 5-phases
  - Pick partner + decide project area
  - Submit intro + related work
  - Propose project plan
  - Build, evaluate, experiment, analyze results
  - Present results + submit final paper (in week 14)
- Grading policy:Presentation(s): 30%, Class participation: 10%, Final project: 50%, Summaries: 10%.

Written Summaries

- Email to me ***before class*** in ASCII text. No Word, Latex, etc
- Summarize key points of all 3 papers for week
  - Main contributions
  - Limitations of the work
  - What you like/not like about paper
  - Any project ideas?
- 20 sentences max per paper
- Summary is quick refresh in even 1 year's time
  - Include main ideas/algorithms, results, etc.
- See handout for more details

Students: Please Introduce Yourselves!

- Name
- Status: grad/undergrad, year
- Relevant background: e.g. coal miner ☺
- Relevant courses taken:
  - ***Systems:*** Networks, OS,
  - ***Advanced:*** machine learning, advanced networks, etc
- What you would like to get out of this class?
  - Understanding a hot field
  - Just a class for masters degree/PhD
  - Compliments your research interests/publications
  - My spouse told me to ☺

Next… Overview

- Brief overview of topics/issues
- Define/motivate area, excite (or discourage) you
- Provoke thinking: More questions, problems than solutions
- Sample of topics to be covered in class
- ALL topics covered in more detail later
- Students may only understand part of topics in today's overview

Mobile computing

- Mark Weiser, Xerox PARC CTO
- 1991, articulated vision (and issues) for ubiquitous mobile computing
- ***Weiser's Vision:***

  "Environment saturated with computing and communication capabilities, with humans gracefully integrated"

- **Core idea:** Invisible hardware/software that assist human
  - ***Hardware:*** smart phones, sensors, tablets, wearable devices, etc
  - ***Software:*** Voice recognition, Mobile OS, Networking/communication software, protocols, etc
- Weiser's vision ahead of its time, available hardware and software
- Example: voice recognition was not available then
- Today, envisioned hardware and software is available

Mobile vs Ubiquitous Computing

- Mobile computing
  - deals mostly with ***passive*** network components
  - Human simply provided universal, seamless network connectivity
  - Human does all the work, initiates all activity, network traffic!!
  - Example: Using ***foursquare.com*** on smart phone
- Ubiquitous computing
  - introduces collection of specialized assistants to assist human in tasks (reminders, personal assistant, staying healthy, school, etc)
  - Networked array of active elements, sensors, software agents, artificial intelligence
  - Builds on *distributed systems* and *mobile computing* (more later)

Ubicomp Sensing

- Sense what?
  - ***Human:*** motion, mood, identity, gesture
  - ***Environmental:*** temperature, sound, humidity, location
  - ***Ubicomp example:***
    - ***Assistant senses:*** Temperature outside is 10F (environment sensing) + Human plans to go work (schedule)
    - ***Assistant advise:*** Dress warm!
- Sensed environment + Human + Computer resources = ***Context***
- ***Context-Aware*** applications adapt their behavior to **context**

Sensing the Human

- Environmental sensing is relatively straight-forward to integrate
- Human sensing is a little harder (ranked easy to hard problems)
  - **Where:** location (easiest):
  - **Who:** Identification
  - **How:** (Mood) happy, sad, bored (gesture recognition)
  - **What:** eating, cooking (meta task)
  - **Why:** reason for actions (extremely hard!)
- Human sensing (gesture, mood, etc) easier with cameras than sensors
- Research in ubiquitous smart environments (office, kindergarten) integrates location sensing, user identification, emotion sensing, gesture recognition, activity sensing, user intent

Mobile Devices

- Smart phones (Blackberry, iPhone, Android, etc)
- Personal Digital Assistants (PDAs)
- Tablets (iPad, etc)
- Laptops



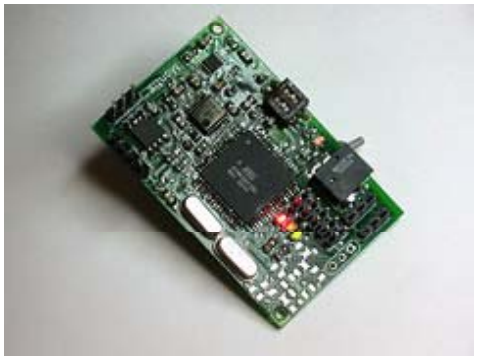


Mobile Devices: Droid

- This class: Google Droid as main mobile device
- Google donated Motorola Droid smart phones
- One assigned project and final project based on Droid
  - Connects to Verizon network, WLAN or Bluetooth
  - Google Android OS
  - 5 MegaPixel camera
  - Streaming video: mpeg, H.264
  - GPS, google maps, etc
  - Sensors: accelerometer, proximity eCompass, ambient light

Sensor Node

- Sensor? Think of automatic doors
- Automatic door sensor has single purpose: detect human
- New multi-functional sensors, programmable for various tasks (intrusion detection, temperature, humidity, pressure, etc)
- Low cost ($1 per sensor), 1000's per room, attach to objects
- Capabilities: Sense, process data, communicate with sink node
- Constraints: Small CPU, OS, programmable



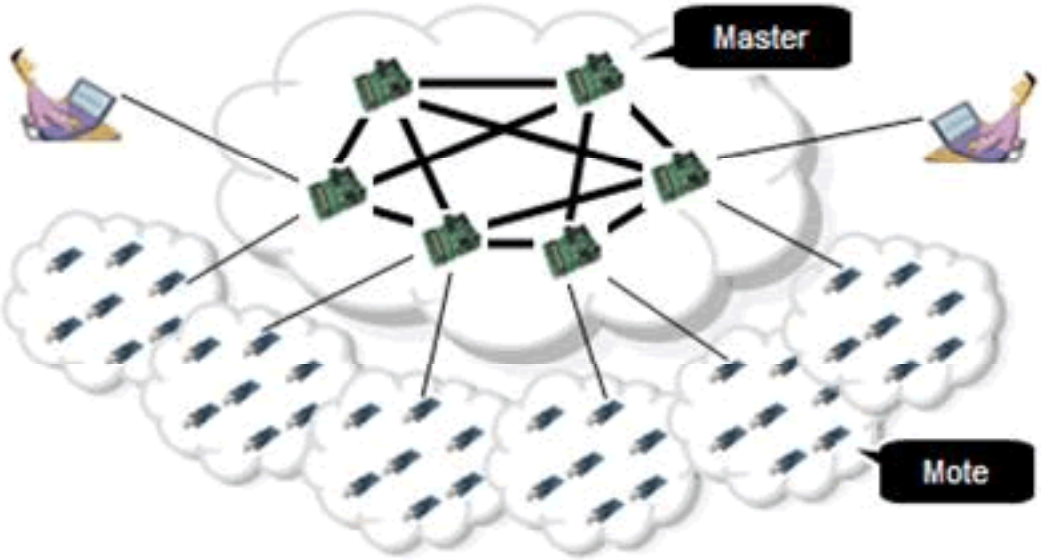
(courtesy of MANTIS project, U. of Colorado)

RFID tags

Tiny Mote Sensor, UC Berkeley

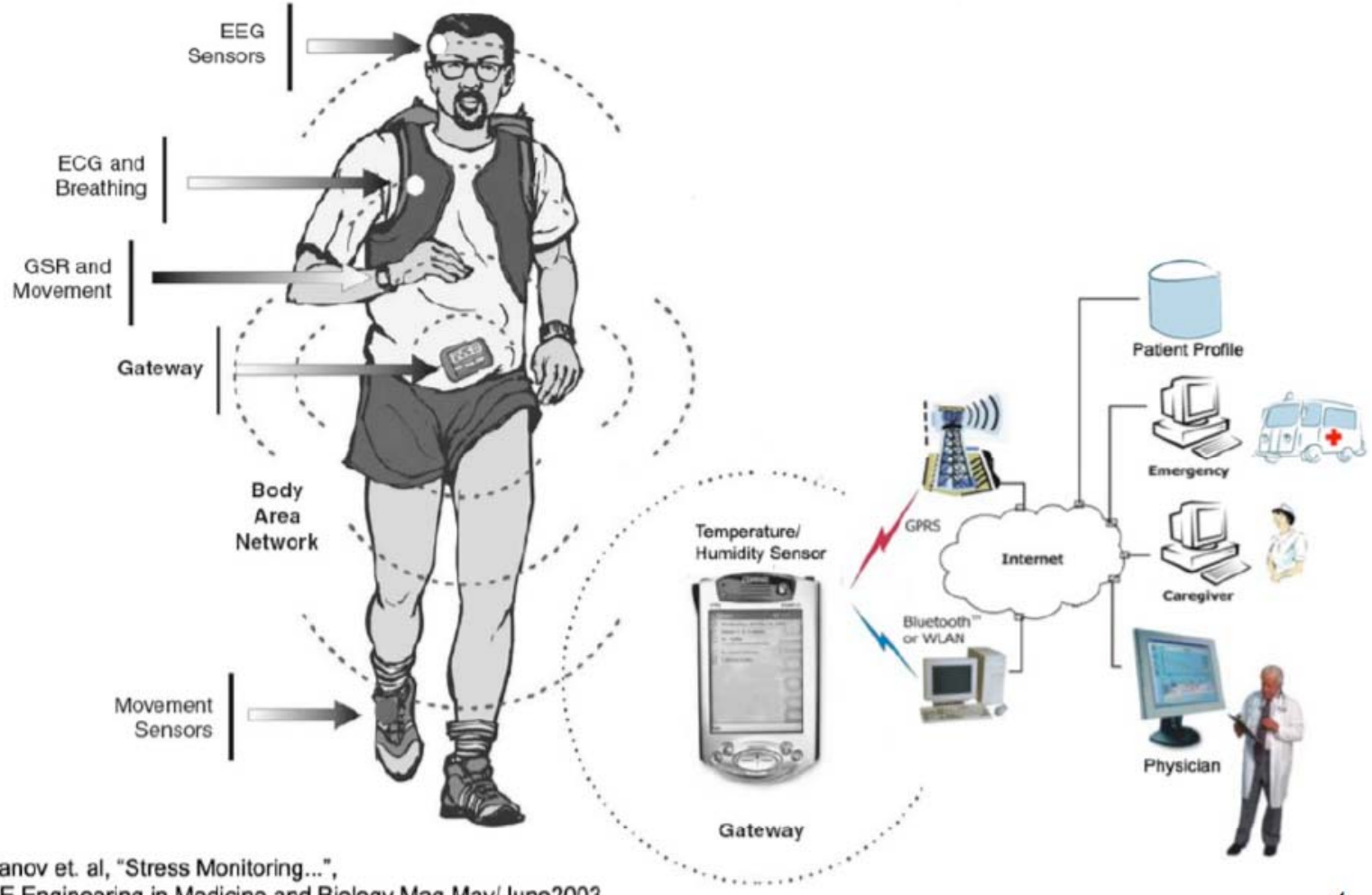
Wireless Sensors for Environment Monitoring

- Embedded in room/environment
- Many sensors cooperate/communicate to perform task
- Monitors conditions (temperature, humidity, etc)
- User can query sensor (What is temp at sensor location?)



Ubiquitous Computing: Wearable sensors for Health

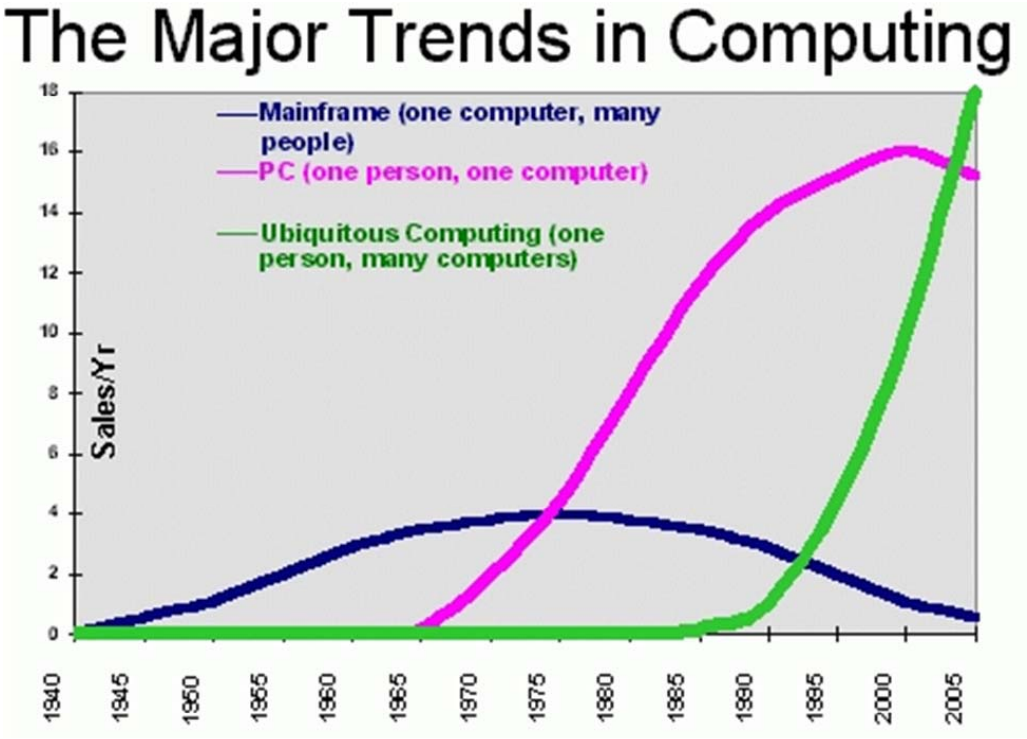
remote patient monitoring



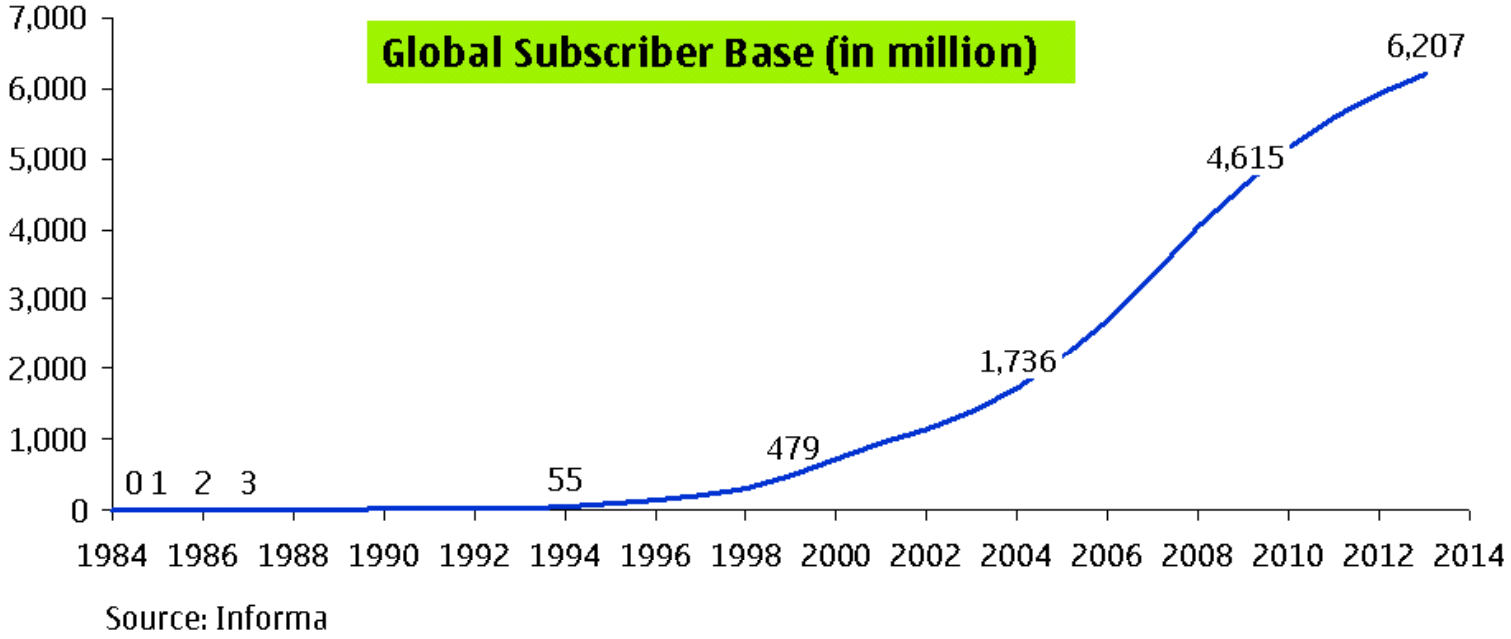
Jovanov et. al, "Stress Monitoring...",
IEEE Engineering in Medicine and Biology Mag.May/June2003

Explosion of Devices

- ***Recent Nokia quote:*** More cell phones than tooth brushes
- Many more sensors envisaged
- ***Ubiquitous computing:*** Many computers per person



Worldwide cellular subscriber growth



Definitions: Portable, mobile & ubiquitous computing

- ***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 that cooperate to help user
- Class concerned mostly with last 2 (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

- Nomadic computing… Nomads… ?

Nomadic Computing

- ***Portable (nomadic) computing example:*** I own a laptop. Plugs into my home network, sit on couch, surf web while watching TV. In the morning, wake up, un-plug, shut down, bring laptop to school, plug into WPI network, start up!
- **Note:** Network is fixed, device moves and changes point of attachment.
- Issues:
  - File/data pre-fetching
  - Caching (to simulate availability)
  - Update policies
  - Re-integration and consistency models
  - Operation queuing (e.g. emails while disconnected)
  - Resource discovery (closest printer while at home is not closest printer while at WPI)
- Note: much of the adaptation in **"middleware"** layer

Mobile Computing Example

- ***Mobile computing:*** Sarah owns SPRINT PCS phone with web access, voice, SMS messaging and can run apps like facebook and foursquare . She remains connected while she drives from Worcester, Massachusetts to Compton, California
- **Note:** Network topology changes, because sarah 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
  - Resource discovery (e.g. print to closest printer)

Ubiquitous Computing Example

- ***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.
- **Core idea:** ubiquitous computing assistants that help John
- 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

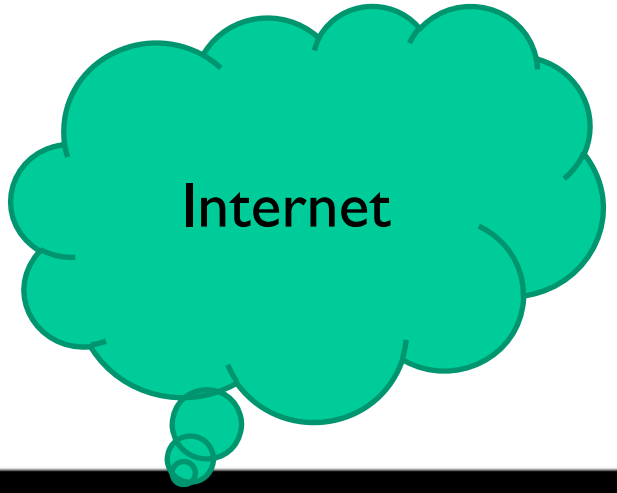
- Systems perspective: nomadic and mobile are ***reactive***, ubiquitous is ***proactive***
- Distributed systems + mobile computing research issues = mobile computing
- Mobile computing + pervasive computing issues = pervasive computing
- In this class, first part will be mobile/nomadic computing, then ubiquitous computing part

Typical of Ubicomp App

Generic:

Location-aware mobile computing apps

- Focus mostly on mobile and ubiquitous computing apps that use Smart Phone and Internet connectivity.
- Example: Location-aware **mobile computing** apps. Issues:
  - **Entropy:** Infering how close two facebook friends are based on locations mutually visited
  - May not want all facebook friends to know exactly where I am
  - Automatically **anonymize location info**
    - **Fact: User is at Starbucks, 180 Main St, Worcester, MA**
    - Status update to friend A: Emmanuel is at "coffee shop"
    - Status update friend B: Emmanuel is at "Starbucks, 180 Main St, Worcester"
    - Algorithms to automatically generate status update (based on closeness)



The Internet as a data source for Location-aware apps

[Identifying the Activities Supported by Locations with Community-Authored Content , Dearman and Truong, Univ. of Toronto *]*

- User at location X would like to make location-based queries
  - What activities can I do here?
  - What's a good close place to do X activity (e.g. soccer)
- Solution: Yelp is a community-authored reviewer website for restaurants, activities, etc
- Yelp has: activities + location + goodness of venues
- Scrape + mine yelp: augment with location as searchable tag

Location-Aware Apps

- Easier location check-in
  - Ubicomp 2010 video p395

Context-Aware Search

[Hapori: Context-based Local Search for Mobile Phones using Community Behavioral Modeling and Similarity, Nicholas D. Lane, Dartmouth College]

- **Goal:** Improves Internet search results using context, such as weather, age, profile of user, time, location and profile of other users to improve search.
- Example: a teenager gets a completely different set of recommendations from and elder.

Mobile Social Networking

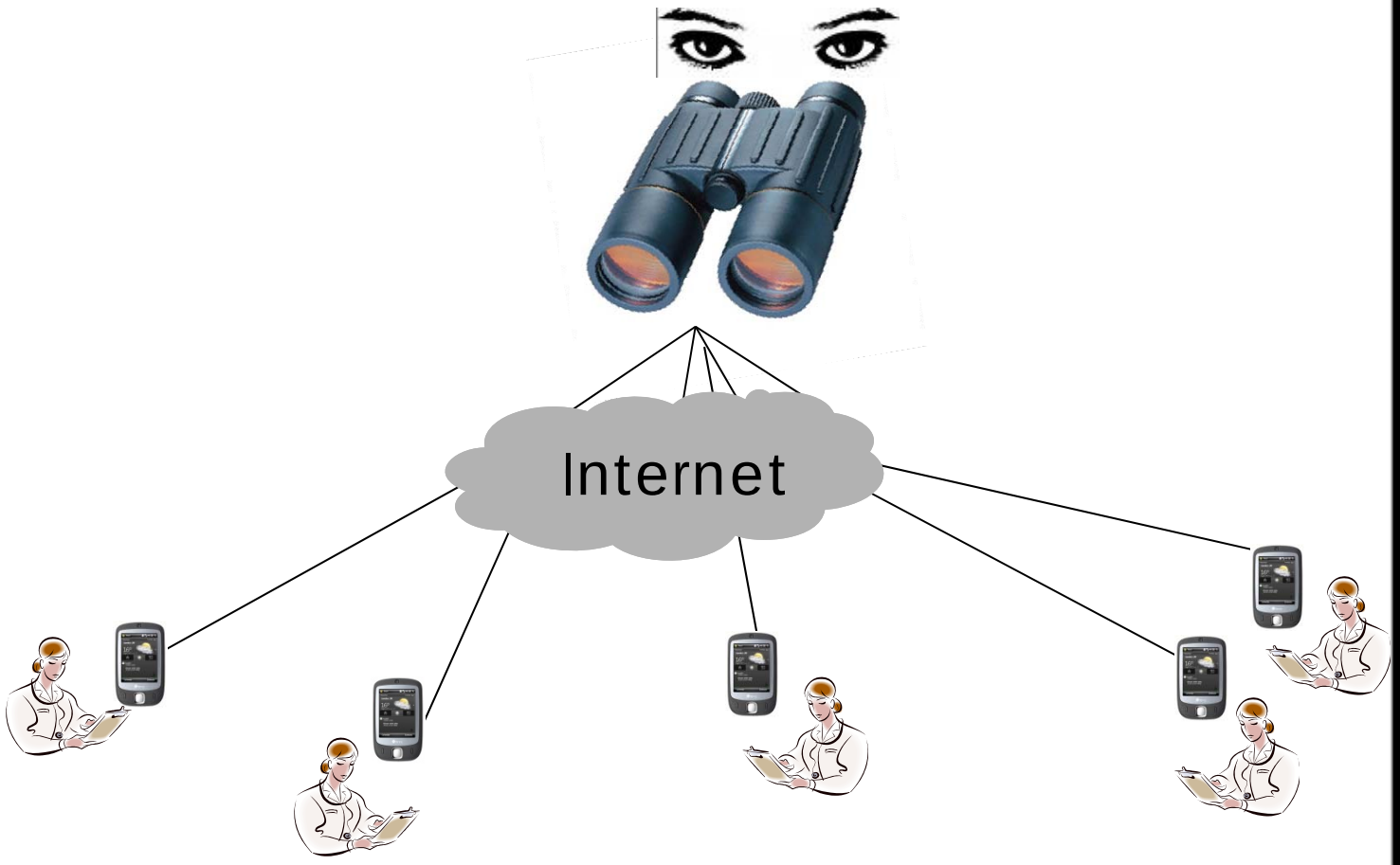
- Partipatory sensing: Many people cooperating on a task
- ***Classic example:*** Comparative shopping
- At CVS, ready to buy toothpaste. Is CVS price the best locally?
- Phone has software to query other members of my network
- People at other local stores (Walmart, Walgreens, etc) respond with prices

UCLA Partipatory Sensing Video

- Demo from UCLA

Mobile Social Networking

- Smart phones have many sensors, cameras, etc
- Imagine ability to access other people's phones: ***Phone Sensing***
- Like a telescopic lens into different locations: ***Microblogging***



Sensing Human Behavior

[Social Sensing for Epidimiological Behavior Change, Anmol Madan et al, MIT Media Lab]

- Goal: infer how falling sick affects the [mobile/network] behaviors of human beings.
- **Examples:** Changes in call rates or visiting low entropy places more could mean person is sick
- Statistics of number of calls, co-location, proximity, WLAN and bluetooth entropy found to be good predictors of illness.
- Findings could be used as an early warning tool.
- If strong inference, then nurse could call the person

Energy Efficiency

- Most resources increasing exponentially ***except*** battery energy (ref. Starner, IEEE Pervasive Computing, Dec 2003)

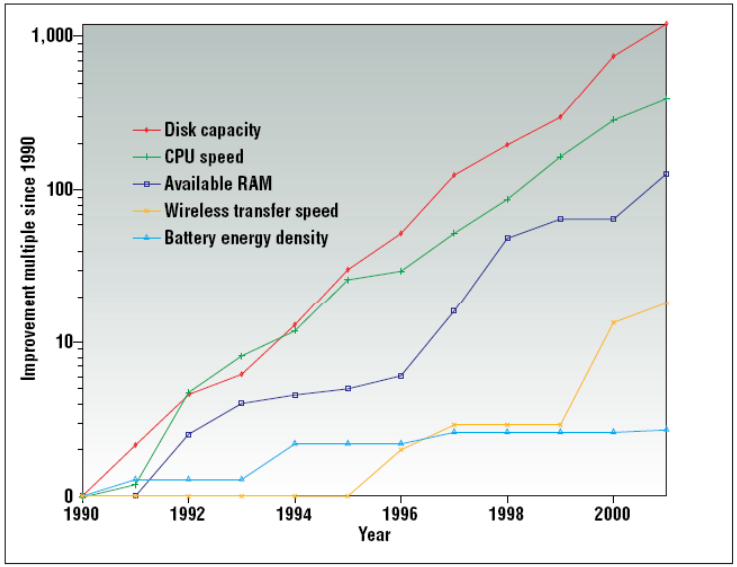


Figure 1. Improvements in laptop technology from 1990–2001.

- Strategies:
  - **Energy harvesting:** Energy from vibrations, moving humans
  - **Scale down:** Reduce image, video resolutions to save energy
  - **Better user interface:** Estimate and inform user how long each potential task will take
    - E.g: At current battery level, you can either type your paper for 45 mins, watch video for 20 mins, etc

Networks for Ubicomp

- Developed countries (e.g. US, UK) have 4 main wide area telecommunications networks (or backbones)
  - Internet
  - Telephone
  - Cable television
  - Cellular phone
- Most are hierarchical: divided into **backbone** and **local loop**
- Only some of these wide area networks in developing nations?
- Internet is main computing backbone

Wireless Networks Papers

- **Characteristics of Web Content *by*** *Timmins et al*
  - Formats, sizes, etc of mobile web pages
- ***Haggle: Seamless Networking for Mobile Applications*** *by Su et al*
  - Framework that manages various available networks, speeds, etc for user
- ***A First Look at Traffic on Smartphones*** Hossein Falaki *et al*
  - Analysis of measured smart phone traffic

Smart Home Infrastructure

[ElectriSense: Single-Point Sensing Using EMI for Electrical Event Detection and Classification in the Home, Sidhant Gupta et al, Univ. of Washington]

- Goal: Activity detection around the home
- Many new appliances have a "soft switch"
- Proposed a sensor for homes, plugged into ***single point***:
  - Train first: captures electric signature of each appliance in home
  - Can then detect device when appliance turned on in future
- Appliance signature was unique and usable at different time home

  E.g: iMac signature is unique. Capture once, use many times

Energy efficiency

- Smart home: energy efficiency
  - Ubicomp 2010 video p361

Wireless Networks Types

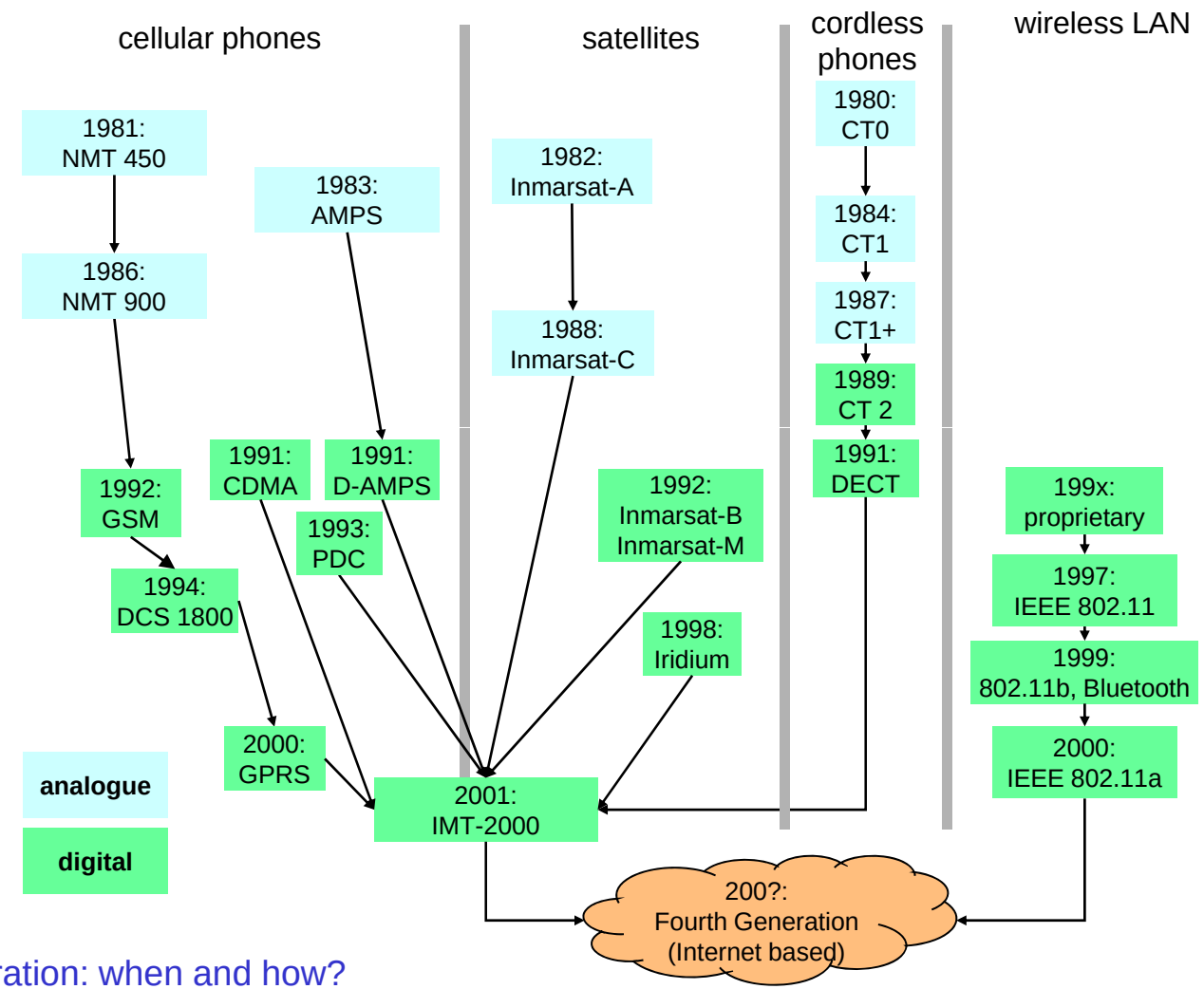
- ***Cellular Network:*** Wide area wireless network operated by Sprint, Verizon, AT&T, etc. 1G (analog), 2G today's network, 3G coming, 4G (in some labs)

- ***WLANs:***
  - ***Infrastructure networks:*** wired backbone (Internet), wireless last hop. E.g WPI wireless LAN, **New:** mesh networks
  - ***Ad hoc networks:*** all wireless, no backbone, no order known in advance. E.g. few deployed examples.. .futuristic

- ***Bluetooth:*** Short range communications, printers, headsets, etc
- ***WiMax:*** Wide area high bandwidth

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

Wireless systems: evolution



4G – fourth generation: when and how?

Ref: Mobile Communications, 2nd edition

Wireless Networking Challenges

- Wireless networking issues
  - Wireless spectrum scarcity (regulated)
    - Low bandwidth, asymmetric, heterogeneous
  - Higher error rates (10^{-3}):
    - multipath fading, noise (engines, microwaves), echos...
    - **Note:** indoor channel is different from outdoor
  - Higher delays, higher jitter
    - Connection time: secs for GSM, > 0.1s other wireless
  - Moving users:
    - Uncontrolled cell population, variable link quality
    - Different points of attachment to network
    - Frequent network disconnections (cell phone)

Wireless Networking Challenges

- Wireless networking issues (contd)
  - Less secure and less robust
    - (e.g. signal leakage)
    - More easily stolen, tampered with (drunk employees)
  - Shared medium
    - Who's turn to transmit, etc
  - Tough to guarantee Quality of Service (QoS)

Wireless Measurement

- Previous versions of class covered wireless protocols, standards
- This version: brief coverage on wireless
  - Usage: measurement studies of wireless LANs and mobile web, wireless mesh networks, etc
  - Programmer perspectives: How to program Android apps for wireless (WLAN, bluetooth, cellular) connectivity
  - Novel wireless frameworks for ubicomp, seamless communications during roaming

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

WLAN Vulnerabilities

- Protocol (e.g 802.11) 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.

Wi-Fi Privacy Ticker

[Sunny Consolvo et al , Intel Labs Seattle , University of Washington]

- Many wireless security/privacy breeches occur
- Many open problems. Some too hard to solve for now
- Examples:
  - website A may send your information to website B without your knowledge
  - New google search sends typed characters BEFORE you hit enter
- **Solution:** Alert to user when info is being transmitted unsecurely
- Ticker streams violations of user's pre-defined breeches
- “Breeches“ identified and importance customizable
- Wi-Fi Ticker increased user awareness about security
- Even highly techno-savvy learned about breeches

Final Words

- This is a **special topics** graduate class
- **Special Topics:** I have picked selected topics that are hot.
- Coverage is not complete
- Graduate class so graduate level work/effort is expected
- Seminar style classes: You get out what you put into them

Homework

- Today: Sign up for papers to present
  - Procedure: Sign up sheet passed around, simply sign
- Summaries of week 2 papers (Smart homes and healthcare): due before next class
- Two weeks: decide project area and partners (if any)
  - Project? Never too early to start thinking about project, talking to me.