This Course

- This is a research course
- Hopefully, I am a participant/moderator, not just the instructor :-)
- Aims of the course
  1. Give us an understanding of the basic issues and challenges in mobile computing and networking
  2. Give us in depth knowledge of selected important topics
  3. Give us an appreciation of open research problems
  4. Provide some research experience and training
     - How to read research papers critically
     - How to relate them to each other
     - How to identify a research problem
     - How to design and set up an experiment to study a problem
     - How to write and present a research paper

Class Format

- We will have two quizzes
- Grading for critiques: -, -/+, =, -/+, +
  - Due at the beginning of class (not in the middle of the class, after the class, or later that evening)
- Everyone will present at least one paper during the semester (up to half hour)
  - Each week will have 1-2 student presenters (usually to cover additional papers)
**Project Timeline**

- You have to write a short proposal discussing and motivating your research project (due Monday of the 6th week of the semester)
- Progress report presentation (10-15 minutes in class), in 10th week of the semester
- Final report due to me at the end of the semester

**Class Participation**

- Class participation is mandatory
  - it is much more fun for all involved if the class is lively
  - If it is quiet, we will have a quiz!
- Critiques + class participation, 20% of grade
- Quizes – 20% of grade
- Presentation(s) – 10% of grade
- Project – 50%

**Experimentation**

- Systems research typically requires analysis to support your idea
  - Build the thing and see how it does
    - We have some infrastructure for projects: mesh network, sensor nodes, planning to get some HP iPAQs or similar
    - Does not have to be original idea, although that is appreciated
  - Mathematical modelling – not all problems lend themselves to this approach
  - Simulation: has to have an original component

**Project**

- You will propose a research study relating to the class topic
  - You will work in groups of up to 3
- Chicken-and-egg? how do you find a problem before understanding the topics?
  - I will help. Will also make a list of possible projects online—prefer you find your own
  - You need to meet as a group, do some background research and brainstorm
First things first – Mobile or Wireless?

- Are Mobile and Wireless equivalent terms?
- Do they imply each other?
- Mobile Computing, Nomadic Computing, Ubiquitous Computing (Pervasive, Invisible, Calm, Sentient, Metamorphic ...)

Expectations

- Class is about: Fundamental issues and challenges in wireless and mobile computing and networking
- Class is not about
  - Wireless communication or propagation (although we can't ignore their effect)
  - Hardware
  - Communication or coding theory
  - Standards and Specific protocols or technologies (only as illustration of concepts and principles)
  - Cellular networks and standards
- In general, targeting breadth, but with depth in some areas

Today

- Brief Introduction and Discussion of Big Issues
- Papers for next two class (these are short and high level; Read them quickly):
  - Dunham, Mobile Databases, anything new?
  - 4G Challenges paper

Some figures from Sumi Helal
Why Wireless

- No cost for installing wires or rewiring
  - Can reach areas where wiring is infeasible or costly (examples?)
  - No delay for setup; “instant connectivity”

- Roaming allows flexibility to stay connected anywhere anytime

- More importantly: big market, consumers are liking what they are getting and expecting more
  - Customers and businesses are willing to pay for it

Why Now?

- Breakthroughs in Technology
  - VLSI and nanotechnology advances: Portable “Information Appliances”: PDAs, sub-notebooks, wearable computing?
  - Infrastructure Enablers: Wireless Communication Networks: Wireless Network covering the world
  - World-wide de-regulation and spectrum auctions

Mobile Computing

- Applications: stand-alone applications, or access to remote applications via
  - Wireless networks: IR, WLANs, Bluetooth, Ad hoc nets, cellular, Satellite, etc...

- Devices: portable PCs, hand-helds, wearable devices, sensors

- Users: Nomadic and Mobile users (people, agents, vehicles, animals, cell phones)
Challenges/Limitations in Mobile Computing

- Presentation based on Forman and Zahorjan's paper
- Mobility Bandwidth Tradeoff

Limited Bandwidth

- Resource gap with respect to wired networks
  - Lower bandwidth/higher latency
  - Variable bandwidth
- High error rates (BER)
- Quality of Service (QoS) difficult to support
- Shared medium, but frequency reuse helps
- Asymmetric connections
- Makes Energy Efficient operation difficult

Limited Bandwidth

- Variable Bandwidth
  - Bandwidth can change dramatically and quickly
  - Applications must adapt to the changing quality of connectivity
    * High bandwidth low latency – great!
    * High bandwidth high latency – use aggressive prefetching
    * Low bandwidth low latency – using caching, asynchronous operation, and generally the same mechanisms used for disconnections

Limited Bandwidth

- Resource gap with respect to wired networks
  - Lower bandwidth/higher latency
  - Variable bandwidth
- High error rates (BER)
- Quality of Service (QoS) difficult to support
- Shared medium, but frequency reuse helps
- Asymmetric connections
- Makes Energy Efficient operation difficult

Limited Bandwidth

- Resource gap with respect to wired networks
  - Lower bandwidth/higher latency
  - Variable bandwidth
- High error rates (BER)
- Quality of Service (QoS) difficult to support
- Shared medium, but frequency reuse helps
- Asymmetric connections
- Makes Energy Efficient operation difficult

Limited Bandwidth

- Resource gap with respect to wired networks
  - Lower bandwidth/higher latency
  - Variable bandwidth
- High error rates (BER)
- Quality of Service (QoS) difficult to support
- Shared medium, but frequency reuse helps
- Asymmetric connections
- Makes Energy Efficient operation difficult

Limited Bandwidth

- Resource gap with respect to wired networks
  - Lower bandwidth/higher latency
  - Variable bandwidth
- High error rates (BER)
- Quality of Service (QoS) difficult to support
- Shared medium, but frequency reuse helps
- Asymmetric connections
- Makes Energy Efficient operation difficult
Disconnections

- Network failure common
  - handoff is common; reconnection not immediate
  - No coverage in area
  - Very low bandwidth available
- Disconnection due to energy
  - Battery out; recharge time
  - Voluntary disconnection/sleep to save energy

Wireless Communications Issues

- Heterogeneity Issues
- Security Concerns
  - Usually Medium is completely accessible both for eavesdroppers or malicious interference
  - Wireless access makes network attachment easy
- Exposure to over-the-air tapping
  - Some wireless networks provide secure airlinks (e.g., CDPD and 802.11 extensions)
  - CDMA/spread spectrum help as well

Disconnections

- Autonomous operation is a must – cannot depend on a server for everything
  - Caching is a good idea
  - Asynchronous operation (Consider disconnection in the middle of an RPC)
  - Prefetching and delayed updates to get around disconnections

Mobility related Limitations

- Networking Issues
  - Usually communicate to device using its network (IP) address
  - Need to dynamically change the address as the user roams in the network
  - Approaches to support address migration
    - Use a broadcast or limited broadcast scheme to find the mobile – not good
    - Use a mobile directory to keep track of the mobiles – not good
    - Use a broadcast or limited broadcast scheme to find a home agent of the mobile – good
    - Use a Mobile-IP solution – very good
  - Approaches to support mobile roaming
    - Use a Mobile-IP solution
    - Use a Global Directory
    - Use a Home Agent

Macro vs. Micro Mobility

The Mobile-IP solution

- Is a special case of the Global Directory with
  - No replication or caching; the directory is distributed among the Home Agents
Mobility related Issues

- Location dependant information
  - How does the mobile get its configuration information?
  - How does it learn about its environment (e.g., find the nearest printer or server)
    - This information changes!
  - Location-aware applications
    - Consider a guide system that gives you information about places as you visit them
    - How do you find out your location?
    - Some of this information may be dynamic; e.g., what is on sale at the closest Circuit city
  - Mobile to mobile application – find me the closest taxi cab

- Lack of mobility-awareness by applications

- Lack of mobility-awareness by the System

Portability Related Limitations

- Portability somewhat depends on the application/device type
  - PDA vs. pager vs. laptop vs. a car mounted device

- Consequences of portability
  - Interfaces (keyboard, display, etc.) must be small
  - Battery cannot be big and heavy
    - Everything must be low power
    - Low power hardware design
    - Low power protocols and algorithms
  - Resources are limited both to keep the weight down but more importantly to keep the power down
    - Low performance
    - Limited storage
    - Vulnerable to data loss – battery runs out, PDA gets run over by a truck, somebody steals the laptop

Discussion

- What are the implicit assumptions in this paper?
- Are there other issues?
- What are the implications on application design?
- What are the implications on OS design?
- What are the implications to database design?
Some Networking Issues

• New Concerns: Wireless Link vagaries, interference, energy efficiency, mobility
• Organization (data vs. voice; last hop vs. multi-hop)
• MAC/air interface design
• Supporting Mobility
• Wireless Transport
• Ad hoc Networks
• Modeling, benchmarking and simulation

Some Mobile Computing Issues

• Supporting Disconnected Operation: disconnected file systems
• Application Aware Adaptation
• Mobile Client Server (other mobility models)
• Mobile Caching and Replication
• Mobile Access to Distributed Data bases
• ACID Relaxation
• Service Advertisement and Brokering
• Mobile Applications

Brief History of Wireless Communication

(Part 1)

• B.C. – Use of light for “wireless communication”
• 1794 – Chappe invented the optical telegraph
• 1831 – Faraday and Henry discover electromagnetic waves and demonstrate induction
• 1861 – Reis invented the telephone principle (Alexander Bell commercialized it in 1876)
• 1864 – Maxwell characterizes waves completely (Maxwell’s Equations)
• 1880s – Hertz experimentally demonstrates wave propagation
• 1895 – Marconi demonstrates wireless telegraph
  – He is often credited as the “inventor of wireless comm.”
  – Long wave transmission – 20kW transmission power
  – 1901 – First transatlantic wireless transmission followed
• 1906 – First Radio broadcast
• 1907 – Commercial transatlantic wireless service (huge towers with lots of transmission power)
  – 300ft antennae with huge power
• 1920 – First commercial Radio Station starts operation in Pittsburgh

Brief History of Wireless Communication

(Part 2)

• 1910s–20s “mobile” transmitters and receivers start to appear after the invention of vacuum tubes (1906)
• 1920 – Marconi discovers short waves
  – short waves bounce off the ionosphere
• 1928 – Baird experiments with TV broadcasting
  – Color TV transmitted
  – First TV station (WGY in NY)
  – 1932 – CBS started
• 1933 – Frequency modulation invented; dramatically improves quality of transmission
• 1950s and 60s – German A-Netz and B-Netz wireless phone networks; other European projects after that
  – No support for roaming
• 1983 – Advanced Mobile Phone System (AMPS) started in the US.
  – Like European projects, all analog.
  – Is Frequency regulation a problem?
More Recent History

- Early 1990s – Fully Digital Systems
  - DECT in Europe
  - GSM in Europe
- Cellular vs. PCS
  - In the US, several competing and incompatible technologies
    - AMPS (analog)
    - IS-136 (D-AMPS, TDMA based digital) – AT&T, Cingular (acquired from Bell South and others)
    - IS-95 (CDMA based digital) – Verizon, Sprint PCS
    - iDen (TDMA based) – NexTel
    - GSM1900 – Cingular
- Data communication systems
  - 1996/1997 HIPERLAN standard from Europe
  - 1997– IEEE 802.11 appears to be the winner
  - More recently: Bluetooth, HomeRF ...
- 1998 – Motorola’s Iridium Satellite network finally operational
- Future – 3G and beyond
  - Emerging technologies, all CDMA based that combine cellular telephony with IP/data networking
  - Include cdma2000, UMTS, GPRS, WCDMA, and EDGE
- Will fill in more details next time