Kyu haeng Lee

Some computer science issues in ubiquitous computing
Ubiquitous computing enhances computer use by making many computers available throughout the physical environment, while making them effectively *invisible* to the user.
Historical Origins and Trends

- Computers are becoming smaller and cheaper over time
  - Originally few computers many operators
    - Machines Expensive and Large
    - People (relatively) cheap
  - Trend toward more computers per person
    - Users may not be tech savvy
    - Even tech savvy users have limited time
    - Minimal intervention is required
- People don't want to be separated from their data
  - But spying on users upsets them
  - And can violate laws - security is important
  - Mobility and wireless access are critical.
Weiser is credited with popularizing ubiquitous computing.

- Ubiquitous computing is NOT:
  - Virtual reality
  - The real world provides input!
  - A PDA or PC called an intimate computer, which takes your attention to get it.

- Ubiquitous computing:
  - Supports a world of fully connected devices.
  - Ensures information is accessible everywhere.
  - Provides an intuitive interface, feels like you are doing it.

Challenges include:
- Wireless bandwidth: high-speed and highly multiplexed.
- Handling mobility.
- User Interface (window systems).
Computational Issues Back in 1993

- Weiser started work in 1988 and reported in 1993
  - Initially Virtual Reality (VR) seemed to have similar design approaches
    - VR gets the computer out of the way (supports intuitive interaction)
    - But VR has serious problems
      - Making sufficiently realistic simulations is expensive (and probably will be for decades)
      - VR locks users away from reality
  - Different from Assistants (e.g. PDA or Intelligent Agents) which work for you
    - Imagine a heavy rock being lifted by an assistant
    - Imagine being able to lift the rock yourself (effortlessly)
  - Informal Goal: Computing for every day life
Contents

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Weiser’s Design Goals

- Ultimate Goal
  - Invisible technology
  - Integration of virtual and physical worlds throughout desks, rooms, buildings and life
- Used the construction of everyday things
Weiser’s Design Approach

- **Liveboard** - digital whiteboard
  - Used as shared display surfaces for collaborative work
  - Large ones
  - Replace physical bulletin boards, etc.

- **Pad** - Notebook-based device
  - Near me
  - Always ran XWindows
  - Used Pen interface

- **Tab** - Tiny information portal
  - Power is a major issue, cannot always change batteries
  - Used COTS Intel 8051 microcontroller
  - Always have one on you, wirelessly connected
  - Small touch-sensitive display screen

- Scatter around the office like post-it notes
Weiser’s Computational Issues

- **Low Power**
  - Reduce Power Consumption
  - \( \text{Power} = \text{Gate Capacitance} \times \text{Voltage} \times \text{Clock Frequency} \)
  - Reduced clocking frequency
  - Reduced voltage
- **Wireless**
  - Wireless data protocols were not widely deployed, still in the lab
  - Capable of accommodating hundreds of high-speed devices for every person
  - Near-field of the electromagnetic spectrum
- **Pen**
  - Pens for very large displays
  - Casual use, no training, naturalness, simultaneous multiple use
  - PARC devised a new infrared pen
Media Access Control (MAC) protocols

- Supports multiplexing broadcast media
- Chose MACA - avoids undetected collisions which garble signals.
  - MACA uses time division multiplexing
  - All nodes must have the same transmission radius
  - Nodes don't transmit when the channel is busy.
  - Message sizes are advertised (to let listeners know how long they need to wait).
  - When a node wants to transmit it sends a Request to Send N Bytes (RTS).
  - When the receiver detects the channel is clear it sends a Clear to Send (CTS) N Bytes
  - If a collision occurs all stations should back off the same amount.

Physical layer was challenging

- FCC regulations and technology drove them to 900 MHz bandwidth
- Low power reduces media contention and avoids FCC regulations
Weiser’s Wireless Networking Issues
2 of 2

- Wide Bandwidth Range
  - MACA needed fairness guarantees
  - Added a Not Clear to Send (NCTS) packet for bandwidth reservation by base stations.
- Real Time Multimedia Protocols
  - QoS needed for streaming multimedia
  - May need higher layer
- Packet Routing
  - Need base station load balancing
  - IP not designed to support mobility
    - However, it is dominant
    - OSI ISO 8473 Connectionless Network Protocol (CLNP) has some mobility support, but is less popular
    - Virtual IP, Mobile IP
Weiser’s Interaction Substrates

- Interaction Substrate is what we call the UI Toolkit
  - Windowed Mouse Point and click (WiMP) are still dominant
  - XWindows designed for networked use
    - It is difficult for windows to move once instantiated at a given X server
    - A new X toolkit that facilitates windows migration
    - Applications need not be aware that moved from one screen to another
    - Bandwidth can vary from Kb/sec to Gb/sec, and with window migration a single application may have to dynamically adjust to bandwidth over time
    - To solve this problem, X-window use at lower bandwidth
  - Display areas vary between physical devices
    - Pads often have tiny interaction areas
    - Liveboards have huge interaction areas
  - Input devices depend on size
    - Pads need pens, since keyboards are too big.
    - Pens needed special script since general handwriting mechanism is too hard
Applications

- Applications
  - Locating People
    - Data acquired from:
      - Log ins to workstations/terminals
      - An Active badge system
    - Useful for
      - Automatic call forwarding
      - Shared Drawing Tools
  - Shared Drawing
    - Data Representation
      - Object based
      - Bit mapped
    - UI Issues
      - How to handle multiple cursors?
      - Use gestures or not?
      - Use an ink based or character recognition model of pen input?
Privacy of Location

- Cellular system need to know the location of devices and their use in order to properly route information
- Solution
  - Central DB of location
    - Privacy controls can be centralized
    - But one break-in there reveals all
    - Transmission of the location information to a central site
    - Centrality is unlikely to scale worldwide
  - Storing information about each person at that person’s PC
    - Programs must query the PC, and proceed through whatever security measures the user has chosen to install
Computational Issues

- Cache Coherence Problem
  - Classical distributed computing problem
  - Consider multiprocessor machine with a single address space
  - If 2 processors have the same location cached, how do they make sure they see the same value?
- How close to the theoretical optimum can on-line cache coherence algorithms get in practice?
  - Especially if pages can be compressed.
Conclusion

- Tabs, Pads, Boards ....
- Ubicomp is likely to provide a framework for interesting and productive work for many more years
- Have much to learn about the details