Pervasive Computing

Parts of the slides are extracted from those of Profs. Mark Weiser, Deborah Estrin, Akbar Sayeed, Jack Stankovic, Mani Srivastava, Esa Tuulari, Qiong Luo, Chung-Ta King, and so on.
The Trends in Computing Technology

1970s

1990s

Late 1990s

Now and Tomorrow?
Pervasive Computing Era
What is pervasive computing?

- An environment in which people interact with embedded (and mostly invisible) computers (processors) and in which networked devices are aware of their surroundings and peers and are able to provide services or use services from peers effectively.
What is pervasive computing?

- Several terms that share a common vision
  - Pervasive Computing
  - Ubiquitous Computing
  - Ambient Intelligence
  - Wearable Computing
  - Context Awareness
  - ...
Pervasive Computing Environments

Pervasive computing devices communicate and take actions.
Goals of Pervasive (Ubiquitous) Computing

• Ultimate goal:
  – Invisible technology
  – Integration of virtual and physical worlds
  – Throughout desks, rooms, buildings, and life
  – Take the data out of environment, leaving behind just an enhanced ability to act
Pervasive Computing Phase I

- **Phase I**
  - Smart, ubiquitous I/O devices: tabs, pads, and boards
  - Hundreds of computers per person, but casual, low-intensity use
  - Many, many “displays”: audio, visual, environmental
  - Wireless networks
  - Location-based, context-aware services

- Using a computer should be as refreshing as a walk in the woods
Smart Objects

- Real world objects are enriched with information processing capabilities
- Embedded processors
  - in everyday objects
  - small, cheap, lightweight
- Communication capability
  - wired or wireless
  - spontaneous networking and interaction
- Sensors and actuators
Smart Objects (cont.)

- Can remember pertinent events
  - They have a memory
- Show context-sensitive behavior
  - They may have sensors
  - Location/situation/context awareness
- Are responsive/proactive
  - Communicate with environment
  - Networked with other smart objects
Smart Objects (cont.)

Smart Appliances

Another beer, please, Hal...

I'm sorry, Dave. I can't do that. The bathroom scale and the hall mirror are reporting disturbing flab anomalies.
Pervasive (Ubiquitous) Computing Vision

“In the 21st century the technology revolution will move into the everyday, the small and the invisible…”

“The most profound technologies are those that disappear. They weave themselves into the fabrics of everyday life until they are indistinguishable from it.”

Mark Weiser (1952 –1999), XEROX PARC

- Small, cheap, mobile processors and sensors
  - in almost all everyday objects
  - on your body (“wearable computing”)
  - embedded in environment (“ambient intelligence”)

Pervasive Computing Enablers

- Moore’s Law of IC Technologies
- Communication Technologies
- Material Technologies
- Sensors/Actuators
First Enabler: Moore’s Law

- Processing speed and storage capacity double every 18 months
  - “cheaper, smaller, faster”
- Exponential increase
  - will probably go on for the next 10 years at the same rate
Generalized Moore’s Law

• Most important technology parameters double every 1–3 years:
  – computation cycles
  – memory, magnetic disks
  – bandwidth

• Consequence:
  – scaling down

Problems:
• increasing cost
• energy
2nd Enabler: Communication

- Bandwidth of single fibers ~10 Gb/s
  - 2002: ~20 Tb/s with wavelength multiplex
  - Powerline
  - coffee maker “automatically” connected to the Internet
- Wireless
  - mobile phone: GSM, GPRS, 3G
  - wireless LAN (> 10 Mb/s)
  - Bluetooth
- Room networks, body area networks
- Internet-on-a-chip
Ubiquitous Information

PAN: Personal area network
Body Area Networks

- Very low current (some nA), some kb/s through the human body
- Possible applications:
  - Car recognize driver
  - Pay when touching the door of a bus
  - Phone configures itself when it is touched

business card exchange (IBM)
Spontaneous Networking

- Objects in an open, distributed, dynamic world find each other and form a transitory community
  - Devices recognize that they “belong together”
3rd Enabler: New Materials

• Important: whole eras named after materials
  – e.g., “Stone Age”, “Iron Age”, “Pottery Age”, etc.

• Recent: semiconductors, fibers
  – information and communication technologies

• Organic semiconductors
  – change the external appearance of computers

• “Plastic” laser
  – Opto-electronics, flexible displays,…

• …
Smart Paper, Electronic Ink

- Electronic ink
  - micro capsules, white on one side and black on the other
  - oriented by electrical field
  - substrate could be an array of plastic transistors
- Potentially high contrast, low energy, flexible
- Interactive: writable with magnetic pen
Interactive Map

- Foldable androllable
Smart Clothing

• Conductive textiles and inks
  – print electrically active patterns directly onto fabrics
• Sensors based on fabric
  – e.g., monitor pulse, blood pressure, body temperature
• Invisible collar microphones
• Kidswear
  – game console on the sleeve?
  – integrated GPS-driven locators?
  – integrated small cameras (to keep the parents calm)?
Smart Glasses

- By 2009, computers will disappear. Visual information will be written directly onto our retinas by devices in our eyeglasses and contact lenses
-- Raymond Kurzweil
4th Enabler: Sensors/Actuators

- Miniaturized cameras, microphones,...
- Fingerprint sensor
- Radio sensors
- RFID
- Infrared
- Location sensors
  - e.g., GPS
- ...
Example: Radio Sensors

• No external power supply
  – energy from the actuation process
  – piezoelectric and pyroelectric materials transform changes in pressure or temperature into energy

• RF signal is transmitted via an antenna (20 m distance)

• Applications: temperature surveillance, remote control (e.g., wireless light switch),...
RFIDs ("Smart Labels")

- Identify objects from distance
  - small IC with RF-transponder
- Wireless energy supply
  - ~1m
  - magnetic field (induction)
- ROM or EEPROM (writeable)
  - ~100 Byte
- Cost ~$0.1 ... $1
  - consumable and disposable
- Flexible tags
  - laminated with paper

Chip (without antenna):
~ 2 mm x 2 mm x 10 μm (fits into 80 μm thick paper!)
Lego

Making Lego Smart:
Robot command Explorer (Hitachi H8 CPU, 32KB RAM, IR)
With J.P. Brown’s Rubik’s Cube-solving robot, a camera photos the cube’s configuration and a PC works out the shortest number of moves needed to solve the cube. The solution is then transmitted.
Putting Them Altogether

- Progress in
  - computing speed
  - communication bandwidth
  - material sciences
  - sensor techniques
  - computer science concepts
  - miniaturization
  - energy and battery
  - display technologies
  - ...

- Enables new applications
- “Post-PC era” business opportunities
- Challenges for computer scientists, e.g., infrastructure
Example Projects

- ETH Zurich The Smart Its Project
- *HP Cooltown project*
- AT&T Sentient System
- Berkeley’s Wireless Sensor Network
- Intel Mote/RFID Project
Idea: Making Objects Smart

The Smart Its Project

• Vision: make everyday objects as smart, interconnected information artifacts
  – by attaching “Smart-Its”

• Smart labels
  – Atmel microcontroller: (ETH Zurich)
    4 MIPS, 128 kB flash
Magnifying Glass

- An object as a web link
  - e.g., by displaying a dynamically generated homepage
  - Contents may depend on circumstances, e.g., context and privileges
  - possibly mediated by different name resolvers
- *HP Cooltown project*
Smart Environment, Dumb Object

- A context-sensitive cookbook with RFID
Can be Context-Aware

- Properties of the ingredients
  - Check whether there is enough of an ingredient
  - Prefer ingredients with earlier best-before date

- Properties of the kitchen
  - Check whether required tools and spices are available

- Preferences and abilities of the cook
  - Prefers Asian dishes
  - Expert in vegetarian dishes
AT&T Sentient System

- Location tracking
- Position monitoring
- Timeline-based context storage
Berkeley’s Wireless Sensor Network

- MICA Motes, sensors, and TinyOS:
Berkeley’s Wireless Sensor Network (Cont.)

- **Sensor nodes**
  - Computing – MCU (micro-controller unit)
  - Sensing
    - Heat, light, sound, magnetism, etc.
  - Wireless communication

- **Sensor networks**
  - Consist of several thousands of sensor nodes
  - To retrieve information about an area of interest
Berkley MICA-2
Intel Next Generation Mote
Our Focus

• Wireless Sensor Networks (WSNs)
  – Wireless PANs
    • 802.15.4 ZigBee
    • ...
  – Sensor nodes
    • MCU Architecture
    • Sensor Modules
    • TinyOS
    • Programming
    • ...

• WSN Applications
  – Surveillance
    • Localization and Tracking
    • Habitant Monitoring
    • Intrusion Detection
    • ...
Textbook
Q&A