

# Advanced Topics in Computer Networks

## Ubiquitous Computing

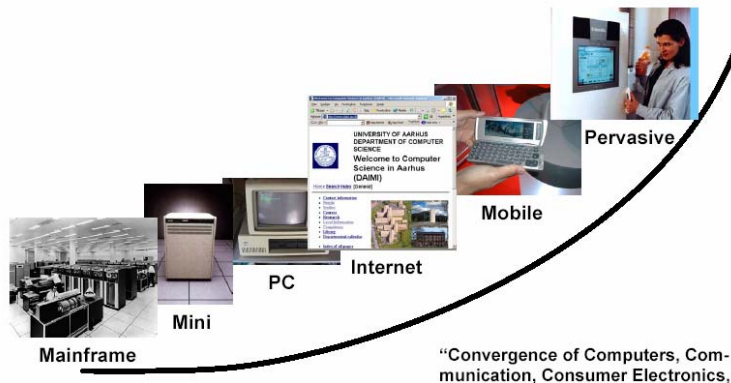
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Slides courtesy of Sumi Helal, Gaurav S. Sukhatme, Mary Baker, Mark Weiser, Jakob E. Bardram, Chansu Yu, and Golden G. Richard III

# Evolution of Computing

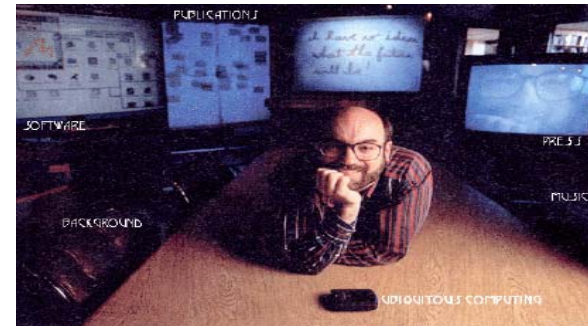
- Single User Systems
- Batch Processing
- Time-Sharing
- Networked Computing
- Mobile Computing
- Ubiquitous/Pervasive Computing

# The Trends ...



"Convergence of Computers, Communication, Consumer Electronics,

# A Vision of an Ultimate Computing Technology



Mark Weiser  
The father of  
Ubiquitous  
Computing

"Profound technologies disappear and become indistinguishable from everyday life"

## Writing: The First IT

- Capture symbolic information of spoken language for long-term storage
- (Almost) No need to depend on human memory
- This technology is now **ubiquitous**
  - it is everywhere
  - we don't notice it
  - don't need to be an expert in 'literacy technology' to access it

## Computers that Vanish

- A new way to think about computers
  - account for human environment
  - think about how and where people live and work
- When people learn something very well, they cease to be aware of it

## Ubiquitous Computing

- Integrate computers seamlessly into the world
  - invisible, everywhere computing
  - Often called *pervasive/invisible computing*
- Augmented reality (Not virtual reality)
  - Ability to query your environment
  - Ability to ask for non-intrusive guidance
- "Using a computer should be as refreshing as a walk in the woods"

## Example: A Responsive Environment

- Office-light brightness will be adjusted automatically according to the daylight
- Your active ID-badge indicates your identity (and your preferences)
- System knows your current location
- Light turns on as you enter a room
- The seat is adjusted to your size



# Ubiquitous Computing Phase I: Tabs, Pads, and Boards (cont.)

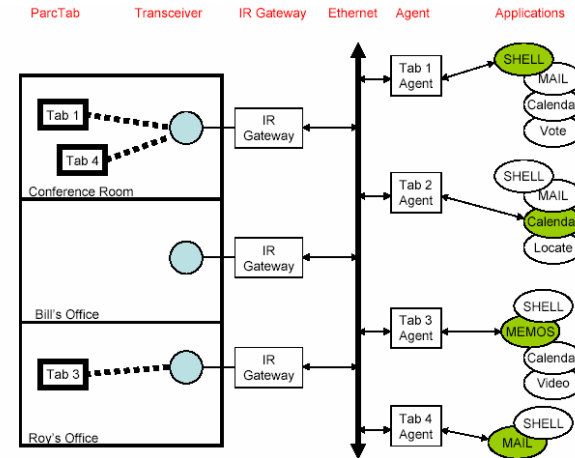
## • Tabs (cont.)

- one hundred per person per office
- processor had low-power mode but was weak
- wirelessly connected (infrared communications)
- small touch-sensitive display screen (128x64 pixels)
- scatter around the office like post-it notes







105mm X 78mm X 24mm  
215g



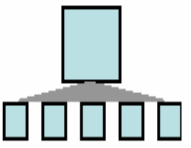
# System Architecture: Wireless Displays



## Tab Applications

- Local (stand-alone mobile device) 
  - application shell, anything that fit
- Aware local (mobile device + sensors) 
  - room information
- External (part of some other application) 
  - locator
- Remote terminal (map mouse, keyboard, display) 
  - weather, dictionary, thesaurus

## Tab Applications (cont.)

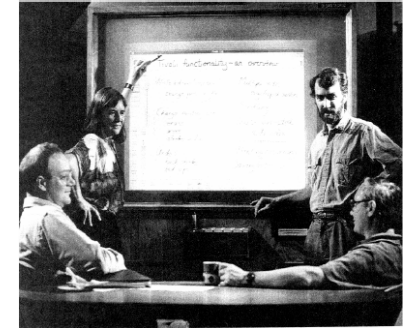
- Remote control (input to some other device) 
  - projectors, media switch
- Networked (version customized to device) 
  - email, pager
- Cooperative (multiple devices, multiple people) 
  - voting, drawing, annotation

## Ubiquitous Computing Phase I: Tabs, Pads, and Boards (cont.)

- Pads
  - paper size
  - portable computers but not laptop metaphor
  - scrap computers - grab and use, no identity or importance
  - ten per person per office
  - near megabit wireless communication bandwidth
  - antidote to windows (use a real desk)
  - can project onto larger computers with a wave of your hand

## Ubiquitous Computing Phase I: Tabs, Pads, and Boards (cont.)

- Boards
  - larger display - whiteboard size
  - personalized electronic bulletin boards
  - multiple pens
  - multi-site
  - informal meetings
  - meeting capture
  - Lots of bandwidth available because they're plugged into the wall



## Ubiquitous Computing Conclusions

- Tabs, pads, and boards are doorways to networked information
- Need mobile infrastructure to make them useful
  - both radio and infrared
- Mobility is nearer-term focus, prior to true ubiquity

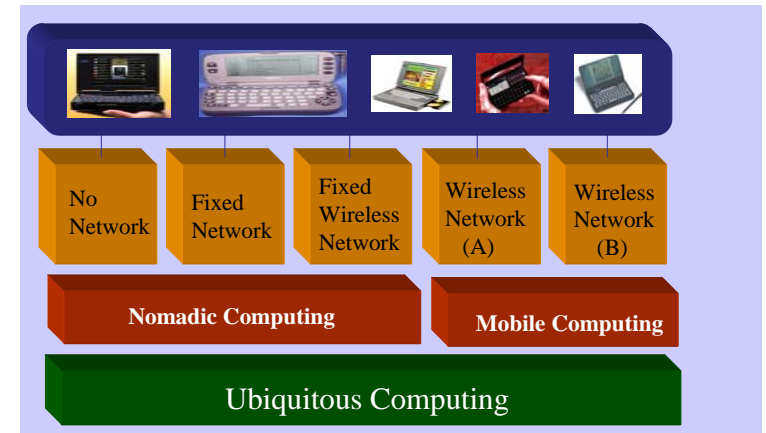
## Mobile Computing

- Using:
  - small size portable computers, hand-helds, and other small wearable devices,
- To run stand-alone applications and access remote ones via:
  - wireless networks: IR, W-LANs, Cellular, W-Packet Data networks and SAT.
- By:
  - nomadic and mobile users

## Ubiquitous, Mobile, and Nomadic

- Terminology not always consistent
  - **Nomadic** computing: "portable"; no mobility while connected
  - **Mobile** computing: "on-the-go", e.g., while sitting on a train; possibility of network connections remaining open
  - **Ubiquitous** computing:
    - computing everywhere... OR
    - *computers everywhere...most of them invisible*

## Ubiquitous, Mobile, and Nomadic (cont.)



## Today's Technology

- **Portable information appliances**
  - laptops, notebooks, and sub-notebooks
  - hand-held computers
  - PDAs and smart phones
- **Wireless communication networks**
  - multiple networks "covering" the globe
- **Internet:**
  - TCP/IP & *de-facto* application protocols

## Portable Information Appliances

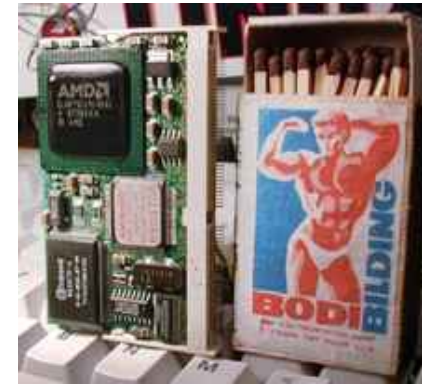
- A variety of computing and communication devices for mobile users
- more computing power ↓
- Watch-sized devices (and usually a watch!)
  - PDA (Personal Digital Assistants)
  - Multifunction cellular phones
  - Palm-sized computers
  - Wearable computers
  - Pads
  - Notebook computers

## Portable Information Appliances (cont.)



(This slide courtesy of Sumi Helal @ The University of Florida)

## Tiny Computers



16MB 66MHz 486SX  
used as a web server

See <http://wearables.stanford.edu/>

## Wearable Computing

Steve Mann's "wearable computer" and "reality mediator" inventions of the 1970s have evolved into what looks like ordinary eyeglasses.



The inventor of wearable computing: Steve Mann.  
See <http://wearcam.org/mann.html>

## Wireless Networking

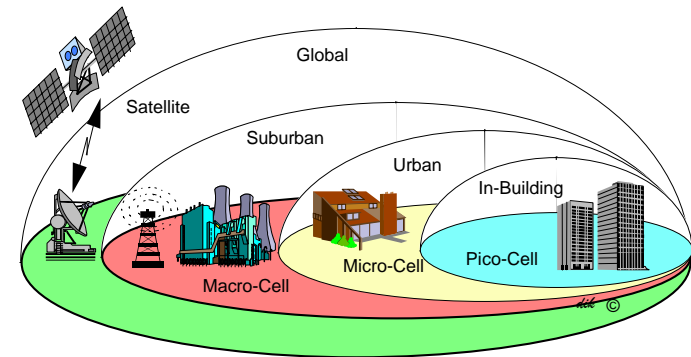
- WAN: Wide Area Network
- MAN: Metro Area Network
- LAN: Local Area Network
- PAN: Personal Area Network

## Wireless Networking Technologies

- Satellite (WAN)
- Microwave (MAN)
- Laser (MAN)
- Cellular (WAN)
- Wireless LANs
- Bluetooth (Wireless PAN)
- IrDA (Wireless point-to-point PAN)

## Global Wireless Infrastructure

Slide courtesy of Sumi Helal @ UFL



## Satellite

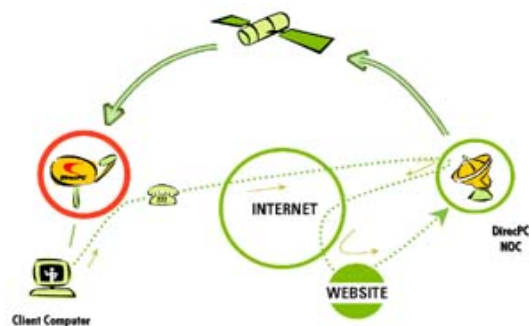
- GEO (Geosynchronous/Geostationary)
  - Remains "stationary" relative to equator
  - Deployed @ 36,000 km—requires a big rocket!
  - Need only 3 to cover earth
  - High latency (1/4 sec or so round trip)
  - Need high-power transmitter to reach satellite
- XM Satellite radio uses GEOs (only 2, though)

## Satellite (cont.)

- LEO (Low Earth Orbit)
  - Much lower orbits—less than 1000 km
  - Must have handoff mechanism—don't appear stationary to earthbound base stations
  - Lower power transmitter than GEO
  - Lower latency, but handoff delay...
  - Space junk!
- MEO (Middle Earth Orbit)
  - ~10,000 km

## Satellite: DirecPC

- ~400Kb/sec downlink from GEO
- Modem uplink (but DirecWAY introduces 2-way)
- Dish must see the sky (typical of satellite)



## Microwave

- Range: 20 miles or more, typically less
- Line of sight *only*, **point to point**
- Rain causes problems, because rain absorbs microwave energy
- Ethernet speeds
- Ducks won't fry



## Laser

- High-speed systems exist: 155Mb/sec
- Line of sight only, ~300m
- Relatively high cost
  - "One complete 155Mb/sec system for \$24K" -- Golden G. Richard III, 2003



## Brief Survey of "Cellular"

- CDPD - Cellular Digital Packet Data
  - Transmit digital data over existing cellular network
  - 19.2Kb/sec
  - Uses idle channels in the cellular network
- Mobitex - Ericsson technology
  - ~8Kb/sec, fairly high latency (4-8s RTT!)
  - Systems exist in US, Europe
  - Migrating to 19.2Kb?
- GSM
  - Most European
  - 9600bps
  - Limited coverage in U.S.



## Wireless LANs

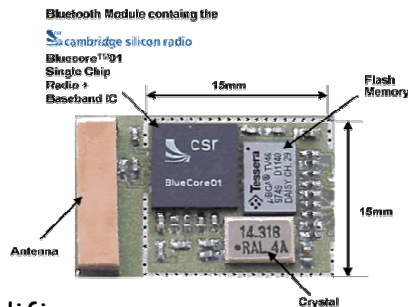
- One example: IEEE 802.11 standard
- CSMA/CA instead of CSMA/CD, as in Ethernet
  - Ethernet: detect collision during transmission
  - Wireless: impossible -- can only hear own signal during transmission
- Current speeds 1Mb/sec - 54Mb/sec
  - 802.11b: 2-11Mb/sec (we have this) in 2GHz range
  - 802.11a: 54Mb/sec in 5GHz range
  - 802.11g: ~20Mb/sec, compatible with 802.11b

## Bluetooth: Goals

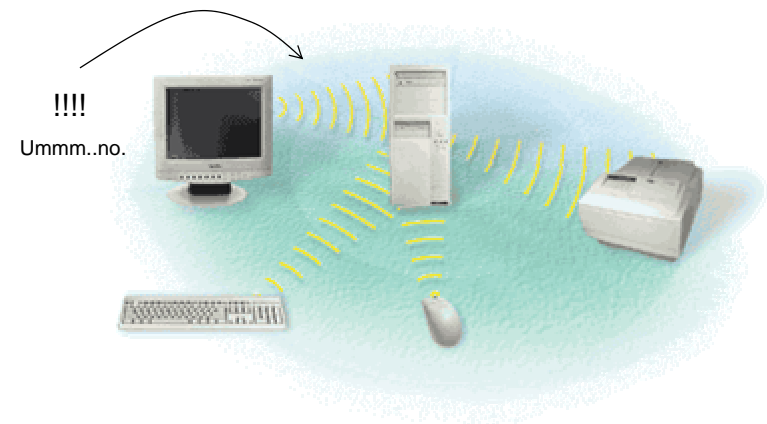
- Provide small, inexpensive, power-conscious radio system
- Personal (short-range) ad-hoc networks
  - Not really intended as a wireless LAN technology
- Device communication and cooperation

## Bluetooth Hardware

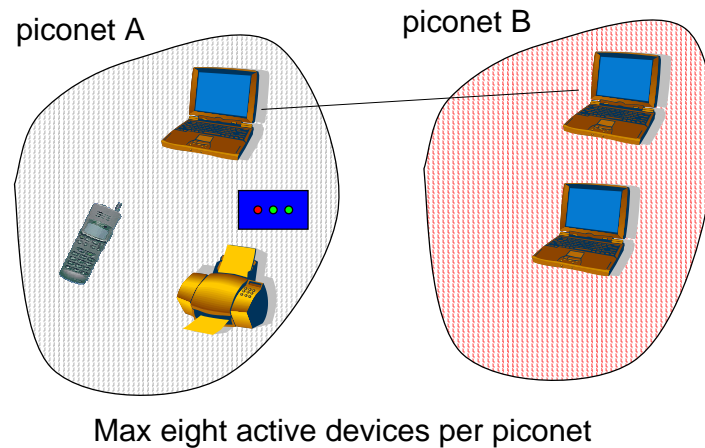
- Predicted long term cost: < \$5/unit
- Low-cost radio operates in the 2.4GHz band
- Bluetooth ~1Mb/sec over several meters
- Range can be extended with an external power amplifier
- Up to 7 simultaneous links
- ~75 hours voice - 3 months standby w/ 600mAh battery



## The Cordless Desktop



## Piconets / Scatternets



## Bluetooth: Concerns

- Frequencies overlap 802.11 standard
- Definitely need integration with software, not just hardware compatibility
- 1Mb/sec isn't fast enough for some applications...
- ...and it definitely isn't enough to replace all cables (monitor, USB, SCSI, etc.)
- But next generation spec may hit 2-20Mb/sec

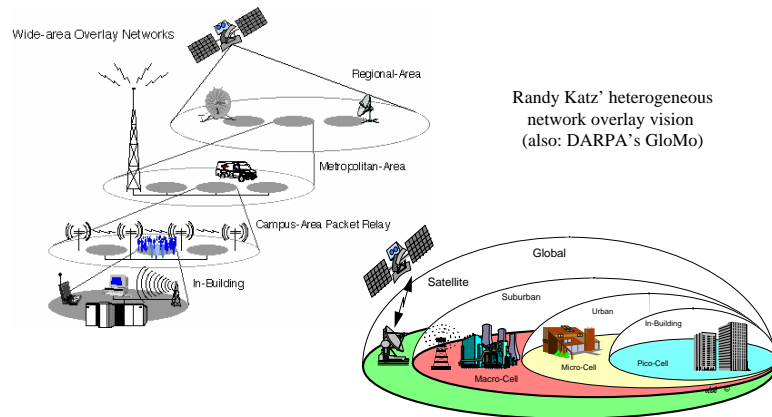
## IrDA

- Line of sight
  - Connected IrDA devices must remain relatively stationary
- Inconvenient for Internet bridge solutions
- Higher bandwidth than Bluetooth
  - 4-16Mb/sec
- Current costs for deployment of IrDA are much cheaper
  - < \$2/unit

## Mobile Computing Challenges

- Limitations of the Wireless Network
  - heterogeneity of fragmented networks
  - frequent disconnections
  - limited communication bandwidth
- Limitations of the Mobile Devices
- Limitations Imposed by Mobility

# Heterogeneity of Fragmented Network Infrastructures



# Frequent Disconnections

- Handoff blank out
  - $>1ms$  for most cellulars
- Drained battery disconnection
- Battery recharge down time
- Voluntary disconnection
  - turned off to preserve battery power, also off overnight
- Theft and damage
  - hostile environment
- Roam-off disconnections

# Limited Communication Bandwidth

- Typically much slower than wired network
  - "State of the art" wireless LAN: 54Mb/sec
  - Wired LAN: 1000Mb/sec+
- Higher transmission bit error rates (BER)
- Uncontrolled cell population
- Difficult to ensure Quality of Service (QoS)
- Asymmetric bandwidth
- Limited communication bandwidth aggregates the problem of limited battery life.

# Limitations of Mobile Devices

- Resource-poor compared to their desktop counterparts
  - Limited processing power
  - Limited memory
  - Limited disk space
  - Limited battery life (max ~ 5 hours)
  - Limited network connectivity
  - Poor availability
    - they sleep a lot! (normally powered-off to conserve battery)
  - Poor display resolution (except notebooks)
  - Tedious data input (except notebooks)

## Limitations of Mobile Devices (cont.)

- Resource poor...
  - Not very expandable
  - Peripherals traded for mobility, so...
  - One device typically doesn't do it all...
    - Poor compatibility between devices
    - Functionality is often duplicated
    - "work belt" syndrome for the mobile computing nerd
    - **Bluetooth** will help, but bandwidth limited
- Need service discovery and better device cooperation

## Limitations of Mobile Devices (cont.)

- Limitations are a result of tradeoffs between portability and horsepower:
  - Very small size limits traditional I/O methods
    - New ones: handwriting recognition, voice input
    - Must work well or extreme frustration...
    - Must work with other people present!!
  - Batteries weigh more than any other component in most mobile devices
    - Smaller batteries, less power
    - CPU speeds reduced to conserve power

## Limitations Imposed by Mobility

- **Lack of mobility-awareness by the system**
  - *network*: existing transport protocols are inefficient to use across heterogeneous mix of fixed/wireless networks
  - *session and presentation*: inappropriate for the wireless environment and for mobility
  - *operating systems*: lack of env. related conditions and signals
  - *client/server*: unless changed, inappropriate and inefficient

## Limitations Imposed by Mobility (cont.)

- **Lack of mobility-awareness by applications**
  - inherently transparent programming model
  - lack of environment test and API support