CS 294-7: Challenges of Mobile Computing

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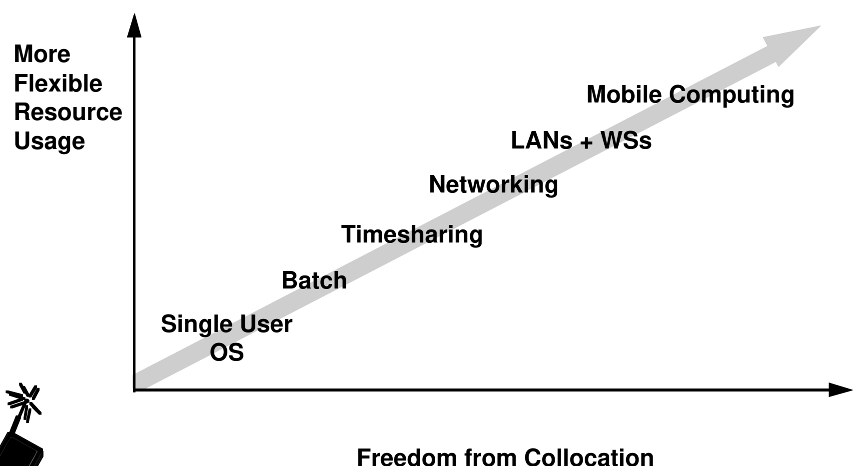
1

Natural Evolution of Computing



2

Research Issues in Mobile Computing

- Wireless Communications
  - Quality of connectivity
  - Bandwidth limitations
- Mobility
  - Location transparency
  - Location dependency
- Portability
  - Power limitations
  - Display, processing, storage limitations

Classes of Mobile Devices

- Display Only
  - InfoPad model: limited portable processing
  - Constrained to operation within prepared infrastructure, like a cordless phone
  - Advantages with respect to power consumption, upgrade path, lightweight, impact of lost/broken/stolen device
- Laptop Computer
  - Thinkpad model: significant portable processing, operates independently of wireless infrastructure
  - Disadvantages: power consumption, expensive, significant loss exposure, typically greater than 5 pounds
- Personal Digital Assistant
  - Somewhere between these extremes

Wireless Communications

- **Harsh communications environment:**
  - Lower bandwidth/higher latency:
    good enough for videoconferencing?
  - Higher error rates
  - More frequent disconnection
  - Performance depends on density of nearby users but inherent scalability of cellular/frequency reuse architecture helps
- **Connection/Disconnection**
  - Network failure is common
  - Autonomous operation is highly desirable
    - » Caching is a good idea, e.g., web cache
  - Asynchronous/spool-oriented applications, like mail or printing
    - » Trickle back data when bandwidth is available
  - Disconnected file systems: CODA (CMU), Ficus (UCLA)

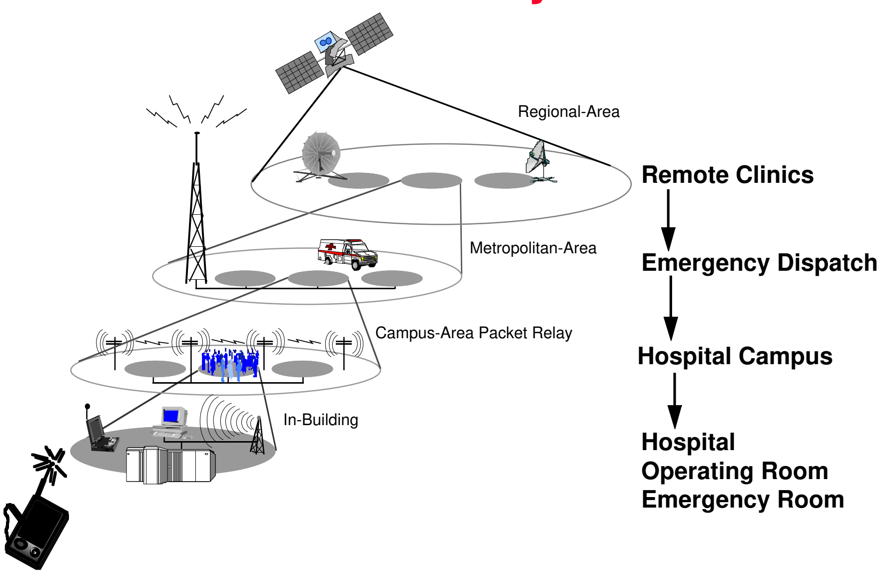
5

Wireless Communications

- **Low Bandwidth**
  - Orders of magnitude differences between wide-area, in-building wireless
- **Variable Bandwidth**
  - Applications adaptation to changing quality of connectivity
    - » High bandwidth, low latency: business as usual
    - » High bandwidth, high latency: aggressive prefetching
    - » Low bandwidth, high latency: asynchronous operation, use caches to hide latency, predict future references/trickle in, etc. etc.
- **Heterogeneous Networks**
  - “Vertical Handoff” among colocated wireless networks

6

Heterogeneous "Wireless Overlay" Networks



7

Wireless Communications Bandwidths and Latencies

Type of Network	Bandwidth	Latency	Mobility	Typ Video Performance	Typ Audio Performance
In-Building	>> 1 Mbps Comm'l RF: 2 Mbps Research IR: 50 Mbps	< 10 ms	Pedestrian	2-Way 'ractive Full Frame Rate (Comp)	High Quality 16-bit Samples 22 Khz Rate
Campus-Area Packet Relay Network	≈ 64 Kbps	≈ 100 ms	Pedestrian	Med. Quality Slow Scan	Med. Quality Reduced Rate
Wide-Area	19.2 Kbps	> 100 ms	Vehicular	Freeze Frame	Asynchronous "Voice Mail"
Regional-Area (LEO/DBS/VSAT)	4.8 kbps–10+ Mbps (asymmetric)	> 100 ms	Vehicular Stationary	Seconds/Frame Freeze Frame	Asynchronous "Voice Mail"

Contrast with 100 mbps Fast Ethernet or 155 mbps ATM
Plus these bandwidths are SHARED among colocated users!

Immediate future: 20 mbps wireless in-building (European HiperLAN)
64 kbps wide area (European GSM)
InfoPad: 200 mbps CDMA radio/2 mbps per user

8

Wireless Communications

- Security Concerns
  - Authentication is critical
    - » Normal network point of attachment is a wall tap
    - » Wireless access makes network attachment too easy
  - Exposure to over-the-air wiretapping
    - » Any transmitter can also be a receiver!
    - » Some wireless networks provide secure airlinks (e.g., CDPD)
    - » Made more difficult by spread spectrum technologies

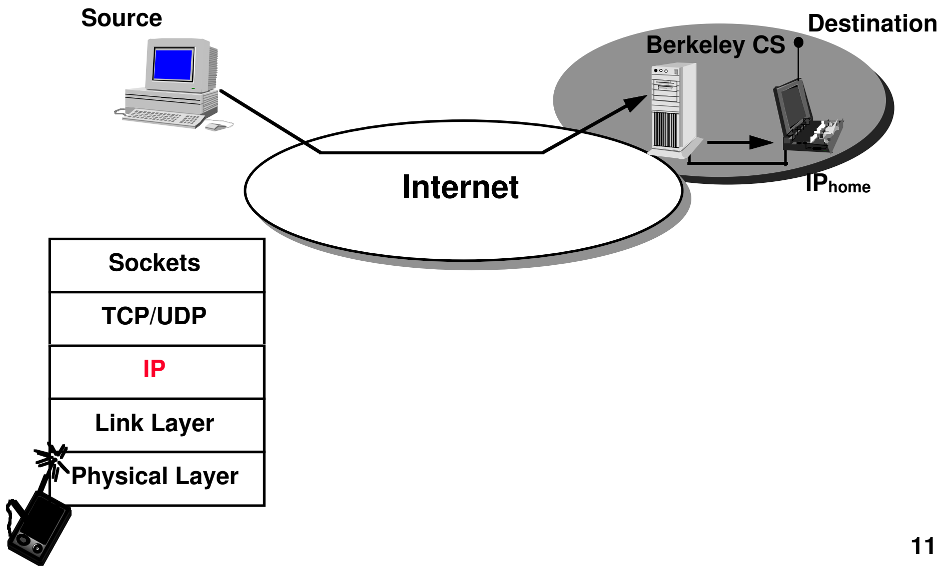
9

Mobility

- Address Migration
  - Existing applications send packets to a fixed network address
  - Need to support dynamically changing “local” addresses as mobile device moves through network
  - Mobile IP specification: home environment tracks mobile device’s current location through registration procedure
  - Route optimization: exploit local caches of <global destination node addresses, current care-of address>
  - Location updates:
    - » Forwarding
    - » Hierarchical mobility agents
  - Other routing issues: e.g., multicast

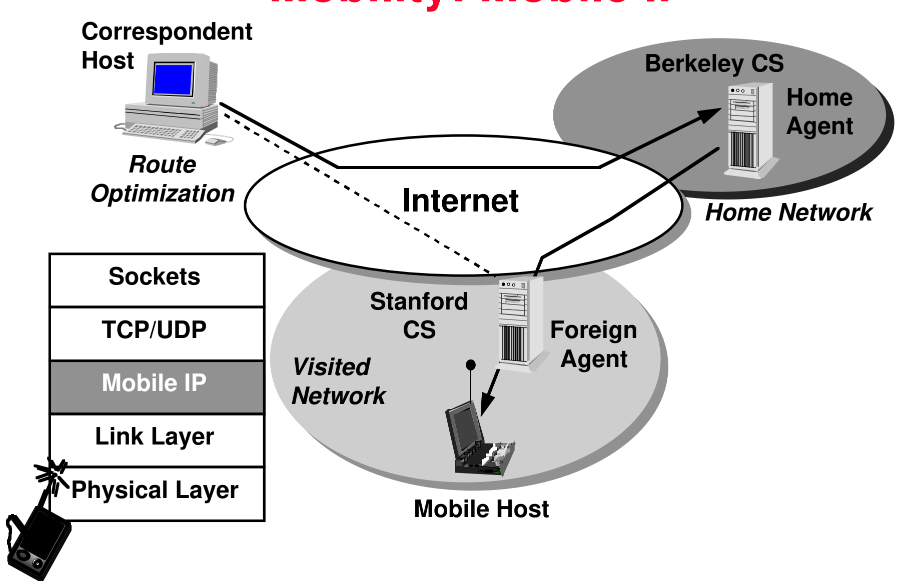
10

Mobility: IP Routing



11

Mobility: Mobile IP



12

Mobility

- Location Dependent Services
  - Discovery: What services exist in my local environment? e.g., printers, file and compute services, special local applications, etc.
  - Follow me services: “Route calls to my current location,” “Migrate my workstation desktop to the nearest workstation screen”
  - Information services:
    - » Broadcast/“push” information (e.g., “Flight 59 will depart from Gate 23”)
    - » “Pull” information (e.g., “What gate will Flight 59 depart from?”)
  - Service migration: computations, caches, state, etc. follow mobile device as it moves through the network
  - Privacy: what applications can track user locations?

13

Portability

- Low Power
  - Limited compute performance
  - Low quality displays
- Loss of Data
  - Easily lost
  - Must be conceived as being “network-integrated”
- Small User Interface
  - Limited real estate for keyboards
  - Icon intensive/handwriting/speech
- Small Local Storage
  - Flash memory rather than disk drive

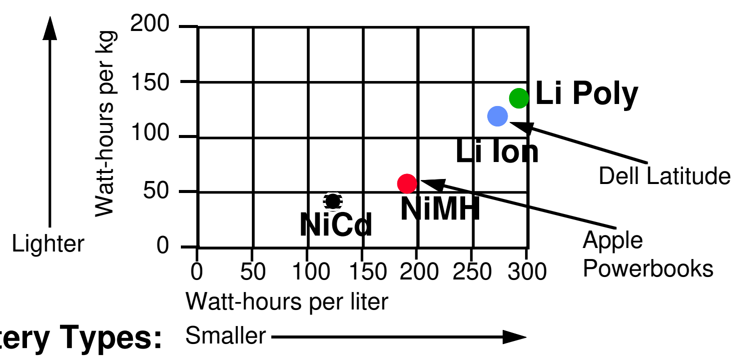
14

Portability Issues

- **It's the power, stupid!!**
- **Batteries**
  - **Weight, volume determine lifetime**
    - » **20 W-hrs per pound**
    - » **2 pounds, 10 hours = 2 W power consumption!**
  - **Power consumption: $CV^2 f$**
    - » **Reduce C by increased VLSI integration and MCM technology**
    - » **Reduce V to lower operating voltages: 5 V to 3.3V to 2.5V and below**
    - » **Reduce f by reducing clock frequency, standby and suspend power modes**
    - » **Intelligent operation: spin-down disk drives**

15

Battery Technology



- **Other Battery Types:**
  - **Lead Acid**
  - **Nickel Zinc**
  - **Rechargeable Alkaline-Manganese**
  - **Zinc Air**

16

Some PDA Product Parameters

	Mem Size	MHz	Proc	Batteries # Hrs	Batteries Type	lbs.	Display Pixels	Display sq in
Armstad Pen Pad PDA 600	128 KBytes	20	Z-80	40	3 AAs	0.9	240x320	10.4
Apple Newton Message Pad	640 KBytes	20	ARM	6-8	4 AAAs	0.9	240x336	11.2
Apple Newton 110 Pad	1 MByte	20	ARM	50	4 AAs	1.25	240x320	11.8
Casio Z-7000	1 MByte	7.4	8086	100	3 AAs	1.0	320x256	12.4
Sharp Expert Pad	640 KBytes	20	ARM	20	4 AAAs	0.9	240x336	11.2

17

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Tandy Z-550 Zoomer	1 MByte	8	8086	100	3 AAs	1.0	320x256	12.4
AT&T EO 440 Pers Comm	4-12 MBytes	20	Hobbit	1-6	NiCd	2.2	640x480	25.7
Portable PC	4-16 MBytes	33+	486	1-6	NiCd	5-10	640x480	40

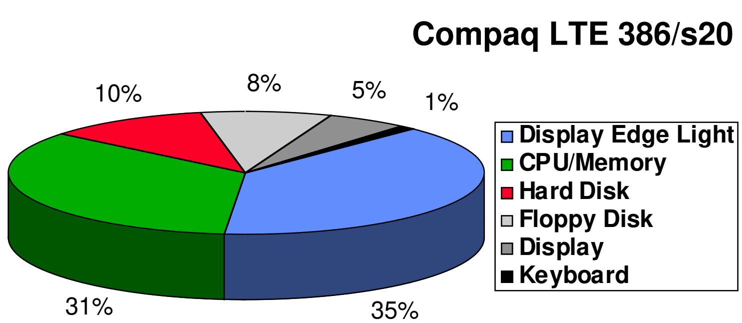
18

Typical Laptop Power Consumption

Base System (2 MB, 25 MHz)	3.650 W	1.8 in PCMCIA hard drive	0.7-0.3 W
Base System (2 MB, 10 MHz)	3.150	Cell telephone (active)	5.400
Base System (2 MB, 5 MHz)	2.800	Cell telephone (inactive)	0.300
Screen backlight	1.425	Infrared network	0.250
Hard drive motor	1.100	PCMCIA modem, 14.4 kbps	1.365
Math co-processor	0.650	PCMCIA modem, 9.6 kbps	0.625
Floppy drive	0.500	PCMCIA modem, 2.4 kbps	0.565
External keyboard	0.490	GPS receiver	0.670
LCD screen	0.315		
Hard drive active	0.125		
IC card slot	0.100		
Additional Mem (per MB)	0.050		
Parallel port	0.035		
Serial port	0.030		

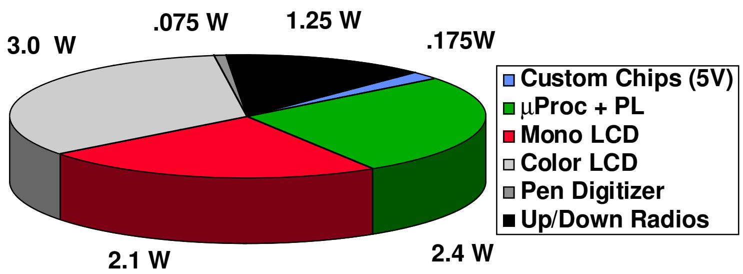
19

Laptop Power Consumption



20

InfoPad Power Consumption



21

Putting It All Together: Concepts in Mobile Computing

- Identification
  - Subscriber mobility: 700 phone number
  - Terminal mobility: mobile phone # or IP address
  - Application mobility
- Registration
  - Authentication: who are you?
  - Authorization: what can you do?
  - Allocation: how much will I give you?
- Call/Connection Establishment
  - Mobile Routing: Mobile IP, Cellular System HLR/VLR
  - Resource Reservations: Reserve channels in advance
  - Location Update: forward vs. hierarchy

22

Putting it All Together: Concepts in Mobile Computing

- **Mobility**
  - **Handoff: when to do it, choice of network**
  - **Process Migration: application support infrastructure that follows the mobile**
- **Privacy and Security**
  - **Authentication**
  - **Authorization**
  - **Encryption: over-the-air security**

23