UNIVERSITY OF CALIFORNIA
MERCED

Mobile Computing

CSE 162
Spring 2021

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Department of Computer Science and Engineering

About me

- Assistant Professor in Computer Science and Engineering
- Research interest
  - mobile computing
  - smart healthcare
  - sensor systems
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Logistics

- Lecture time: 9-10:15 am, Tuesday and Thursday.
  - Zoom link: https://ucmerced.zoom.us/j/82691719033?pwd=bGVTK3NLTnlBYmYrcEhCOXdOTFNtdz09
- Lab session CSE-162-02L time: Tuesday 1:30-4:20 pm
  - Zoom link: https://ucmerced.zoom.us/j/81829921952
- Lab session CSE-162-03L time: Thursday 4:30-7:20 pm
  - Zoom link: https://ucmerced.zoom.us/j/89674753552

- Office hour for Prof. Hua Huang: Thursday 1-2 pm
  - Zoom link: https://ucmerced.zoom.us/j/85860877942?pwd=SkJ5WmtyMzh6ZUIxTFloR3BVMUYwZz09
- Office hour for Hsin-Ping Huang: Friday 10-11 am
  - Zoom link: https://ucmerced.zoom.us/j/86501489282

Rules for Virtual Classes

- Mute while not speaking
- Ask questions in chat or raise your hand before speak
- Webcam encouraged but not required

Textbooks (Optional)

- Ubiquitous Computing: Smart Devices, Environments and Interactions, Stefan Poslad, Wiley Press. (Digital Copy Available through UC Merced Library)
- Mobile Computing, Raj Kamal, Oxfor Press

Grading

- Labs: 35%
- Quizzes: 15%
- Exams: 45%
- Participation: 5%

Communication

- Catcourse
  - lecture notes
  - discussions
  - grades

Honor Policy

- All the homework, labs, and exams are to be done alone
- For the labs, collaboration with other people or group is allowed, but copying each other's solutions is not allowed. Such collaborations is limited to discussing concepts and problems.
- Talk to me if you have questions.

Poll Questions

- Do you?
  1. **Own** Android phones
  2. **Can borrow** android phones
  3. **Do not own and cannot borrow**

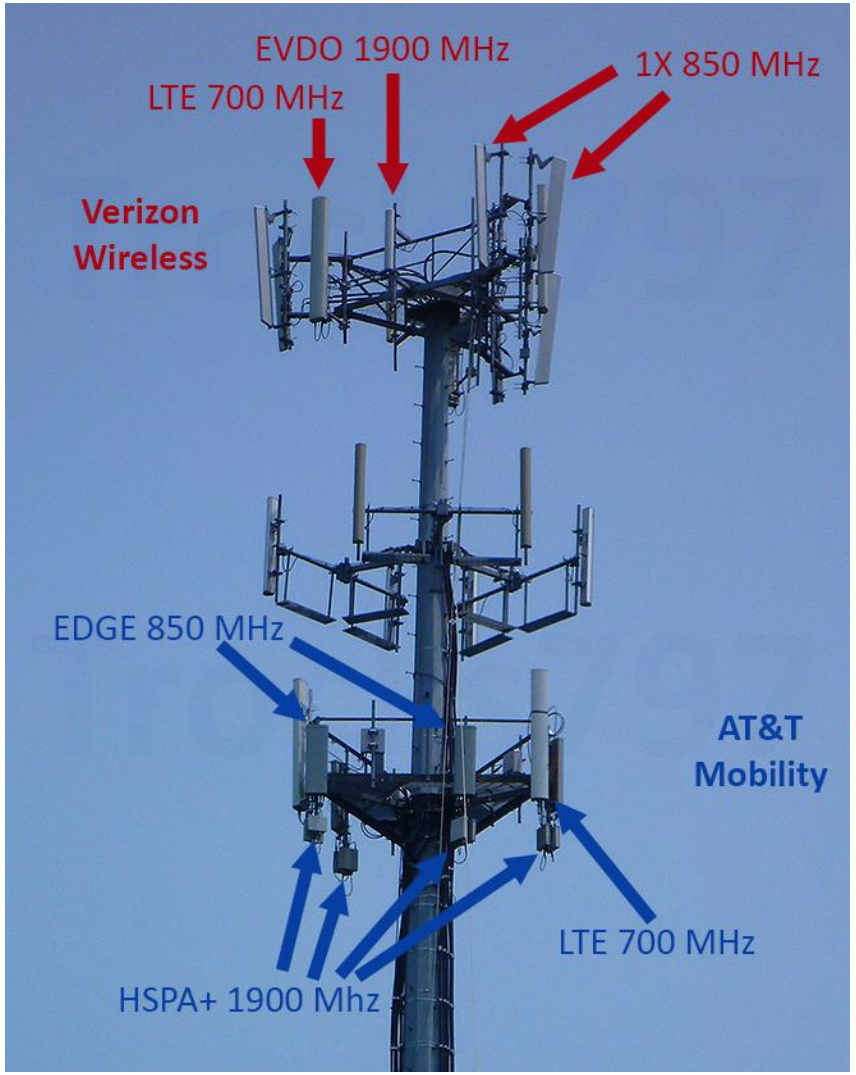
- Either phones or virtual machine implementations are fine.

History of Mobile Computing

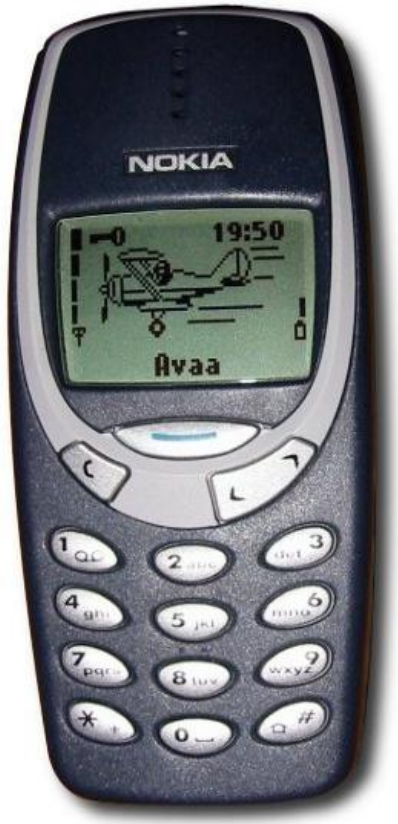
1970s to early 2000:

Consistent innovation in wireless/mobile communication

- On April 3 1973, Motorola engineer Marty Cooper made the first cell phone call
- The DynaTAC phone weighed about 2.2 pounds and was 10 inches long



- Ubiquitous voice. different frequency bands
  - Global System for Mobile communication (GSM)
  - Code Division Multiple Access (CDMA)
- Data connectivity: 3G, 4G LTE, 5G



Mobile Phones were just phones for a while...

- Then things began to change
  - More and more people own mobile phones
  - Batteries got better, form factors improved, coverage improved, plans were better…
  - New applications besides communication become available
  - The handset manufacturers didn’t want to write all the applications for these new phones
  - However… they didn’t want to open up their platform…
  - The first mobile web platform was born (client-server model)

WAP

- Wireless Application Protocol
- Basically it’s a stripped-down HTTP that was meant to be better at transmitting over the unreliable mobile network

Mobile Phone Economies

- Before there were app stores, purchases were made through SMS
  - Send a text message to a pay-per-text number and they would respond with a ringtone or wallpaper or something else
- Some purchases could be made through platform holder services
  - V-Cast is a mobile application that allows users access and download various forms of entertainment and media from their cell phones.

When there’s money to be made...

- The Internet was full of media that people wanted to consume on the go
- Other handheld devices were selling like gangbusters (Game Boy)
- Phones seemed like an obvious next step
  - A computer that everyone carried with them and was always connected

Bigger and bigger players get involved

- Nokia had a large portion of the mobile phone market early on
- Other players like Blackberry, Samsung, HTC, etc. also were involved
- Each had (basically) their own operating system, which made third-party development tricky
- What changed with phones?
  - Phones started running existing operating systems (Windows CE and Linux)
  - Mobile carriers started to relax the constraints on what phones could do

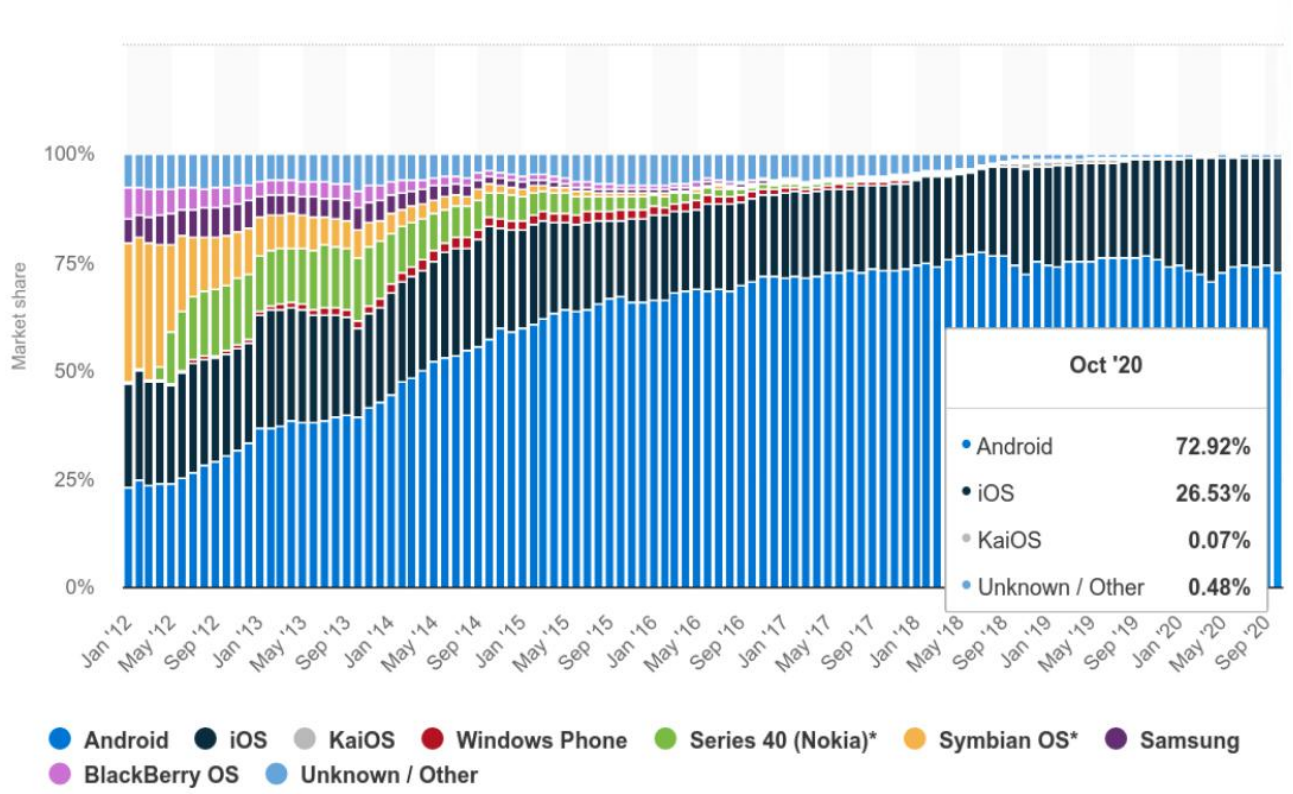
The Market Fractures

- Microsoft
  - Tried to leverage “write once, run on any Windows device” a bit
  - Worked for a while with PDAs, but never really caught on with phones
- Apple
  - Started off as a phone that had a web browser and iPod bolted on
  - Evolved into much more once the App Store opened
- Google
  - Just provided the OS and let others build the devices (for a while)
  - Open source OS + no developer fees = lots of interest and apps

Two Main Operating Systems Remain

- iOS
  - iPhones and iPads only
  - Objective-C or Swift using Xcode OR third party platforms (Unity, Xamarin, etc.)
  - Tightly controlled
- Android
  - Thousands of different devices of all shapes and sizes
  - Java using Android Studio OR third party platforms (Unity, Cordova, etc.)
  - Open Source, available to everyone

Mobile OS Market Share



- Android: 92.9%
- IOS: 26.5%

Mobile Devices

Mobile Devices

- Smart phones (Blackberry, iPhone, Android, etc)
- Tablets (iPad, etc)
- Laptops
- Smartwatches

Smartphone Hardware

- Smart = Communication + Computing + Sensors
  - **Communication**: Cellular data, Wifi, bluetooth, NFC
  - **Computing**: Java apps, JVM, apps
    - Powerful processors: Quad core CPUs, GPUs
  - **Sensors**: Camera, video, location, temperature, heart rate sensor, etc

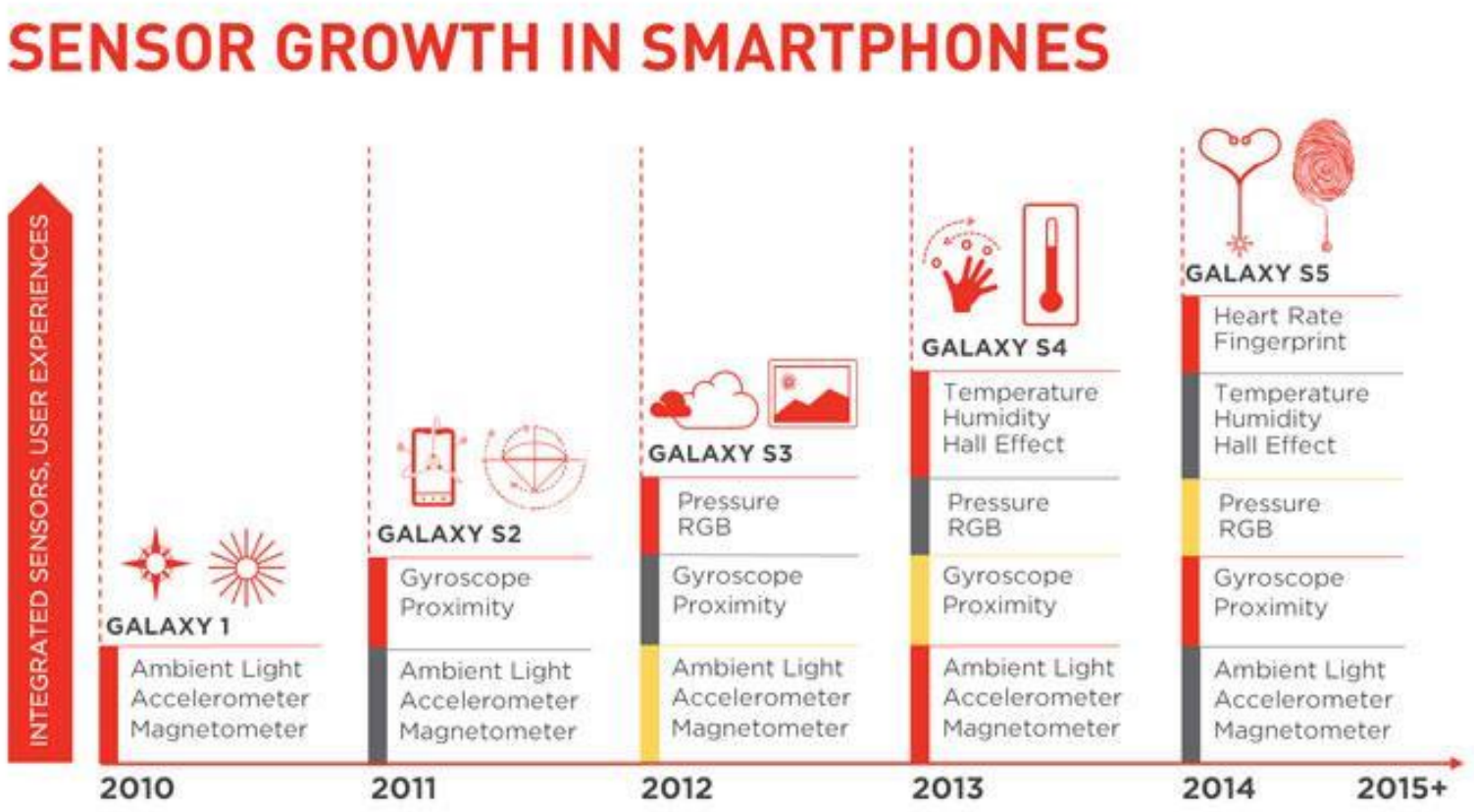
- Google Pixel XL 3 phone: 8 core 2.5 GHz/1.6GHz kryo CPU, Adreno
  - A PC in your pocket!!
    - 630 GPU, 128GB RAM
    - Multi-core CPU, GPU
  - Sensors
  - Runs OpenGL ES, OpenCL and now Deep learning (Tensorflow)

Smartphone Sensors

- Typical smartphone sensors today
  - accelerometer, compass, GPS, microphone, camera, proximity
- Can sense physical world, inputs to intelligent sensing apps
  - E.g. Automatically turn off smartphone ringer when user walks into a class

Growth of Smartphone Sensors

- Every generation of smartphone has more and more sensors!!

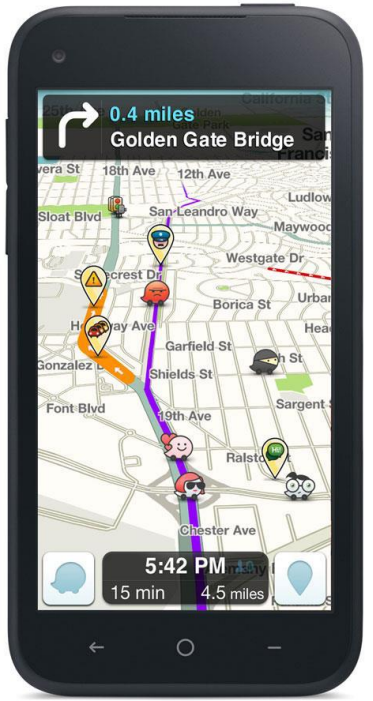


More:

- LIDAR
- mmWave
- pollution sensor

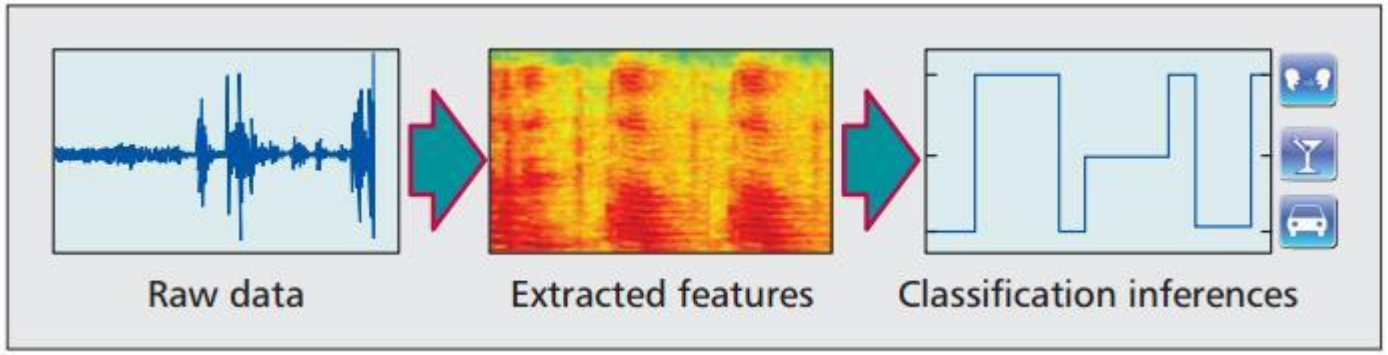
Mobile Sensing

- Mobile devices can sense human, environment
- Example: Human activity sensing (e.g. walking, driving, climbing stairs, sitting, lying down)
- Example 2: Waze crowdsourced traffic

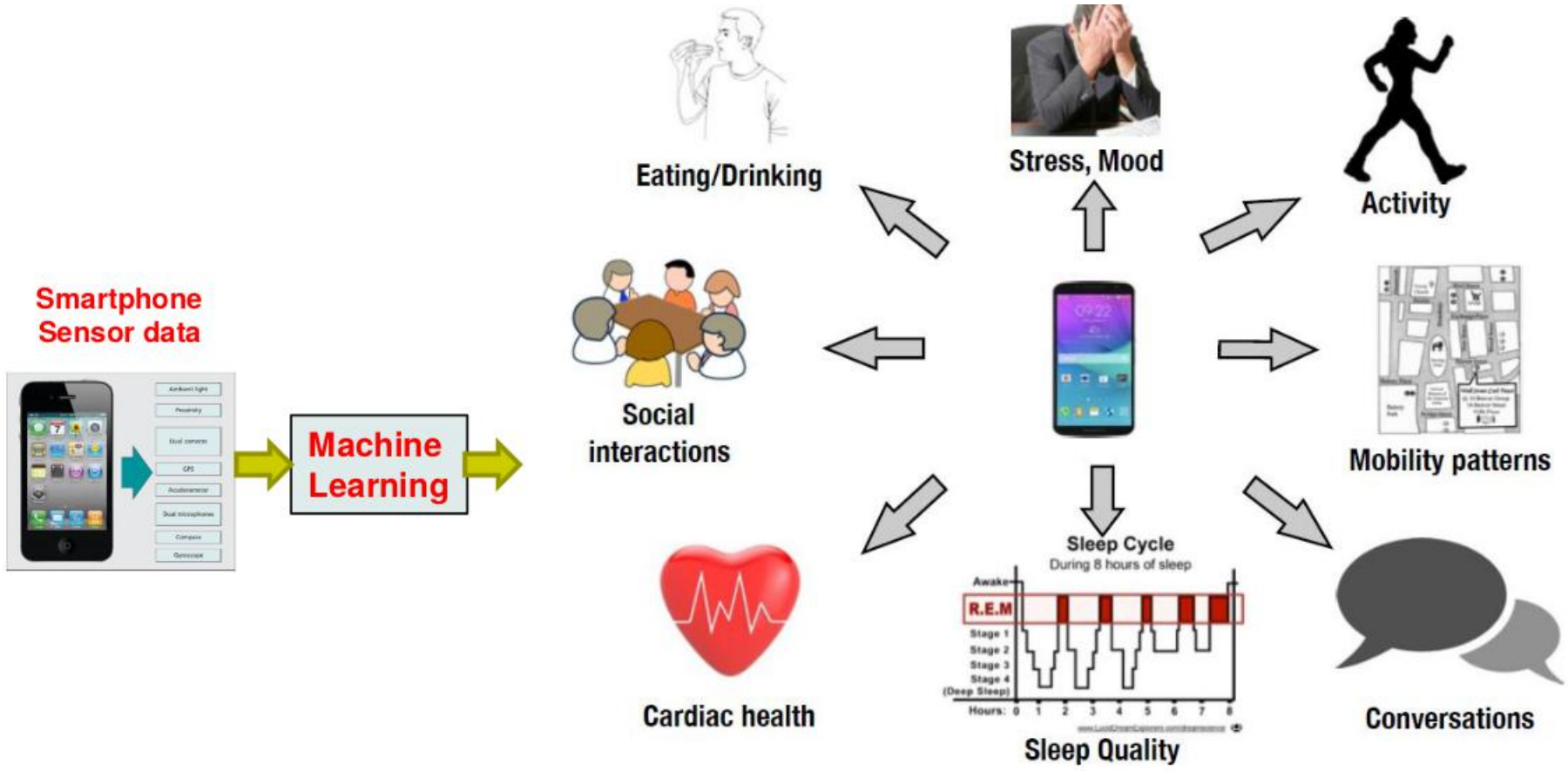


Sensor Data Processing

- Machine learning commonly used to process sensor data
  - Action to be inferred is hand-labelled to generate training data
  - Sensor data is mined for combinations of sensor readings corresponding to action
- Example: Smartphone detects user's activity (e.g. walking, running, sitting,) by classifying accelerometer sensor data



What can be detected by the phone?



Wireless Networks

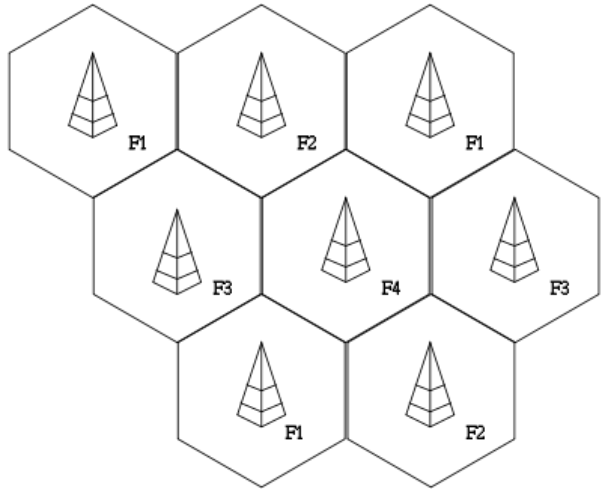
Wireless Network Types

- Wi-Fi (802.11): (e.g. Starbucks Wi-Fi)
- Cellular networks: (e.g. Sprint network)
- Bluetooth: (e.g. car speaker)
- Near Field Communications (NFC)
  - e.g. Mobile pay: swipe phone at dunkin donut

Bluetooth

WIFI

NFC



Celluar Networks

Wireless Networks Comparison

Network Type	Speed	Range	Power	Common Use
WLAN	600 Mbps	45 m – 90 m	100 mW	Internet.
LTE (4G)	5-12 Mbps	35km	120 – 300 mW	Mobile Internet
3G	2 Mbps	35km	3 mW	Mobile Internet
Bluetooth	1 – 3 Mbps	100 m	1 W	Headsets, audio streaming.
Bluetooth LE	1 Mbps	100+ m	.01–.5 W	Wearables, fitness.
NFC	400 kbps	20 cm	200 mW	Mobile Payments

Challenges in Mobile Development

Overview

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

Frequent Disconnections

- Handoff blank out (>1*ms* for most cellulars)
- Drained battery disconnection
- Voluntary disconnection (turned off to preserve battery power, also off overnight)
- Roam-off disconnections

Limited Wireless Bandwidth

- Orders of magnitude slower than fixed network
- Higher transmission bit error rates (BER)
- Mutual interference
  - Difficult to ensure Quality of Service (QoS)
  - Availability issues (admission control)
- Asymmetric duplex bandwidth
- Limited communication bandwidth exacerbates the limitation of battery lifetime.

Limitations of Mobile Devices

- Short battery lifetime and theft or destruction => unreliable
- Sometimes unavailable (disconnection or turned-off)
- Limited capability (display, memory, input devices, and disk space)
- Device heterogeneity: phone, smartwatch, laptops, and other devices

Battery limitations

- Most resources increasing exponentially except battery energy

- Strategies:
  - Energy harvesting: Energy from vibrations, moving humans
  - Scale content: Reduce image, video resolutions to save energy
  - Auto-dimming: Dim screen whenever user not using it. E.g. talking on phone

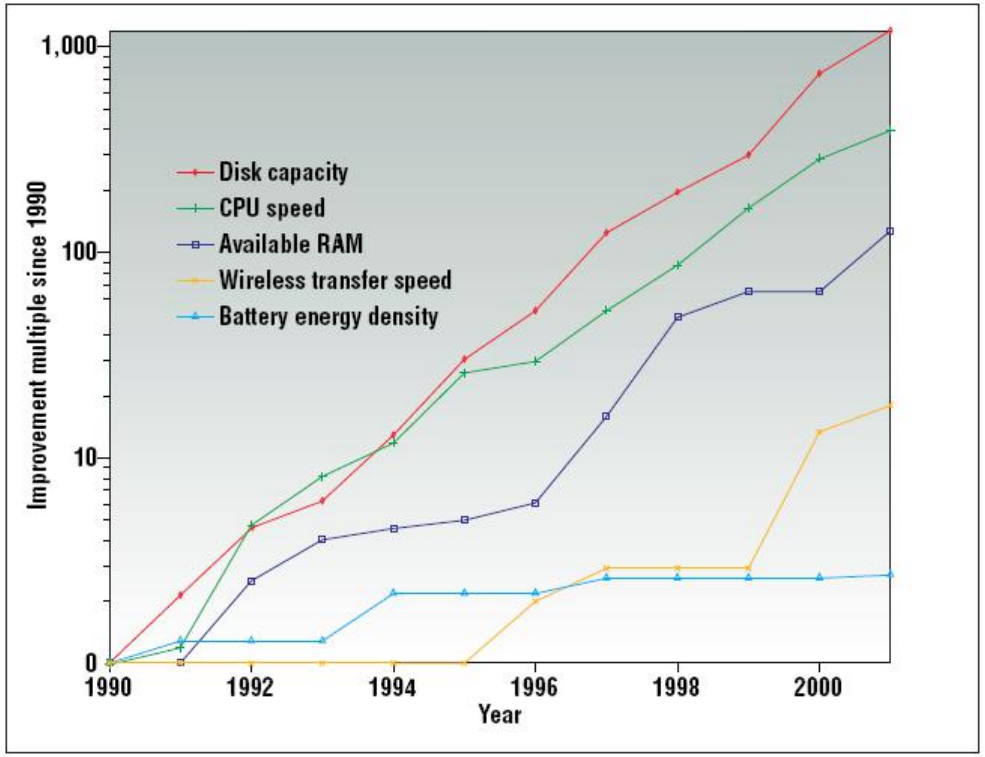
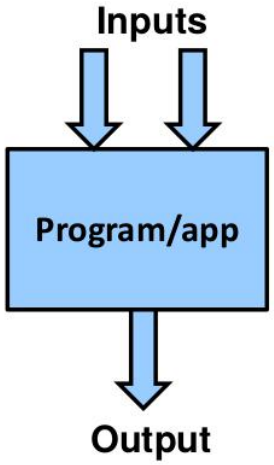


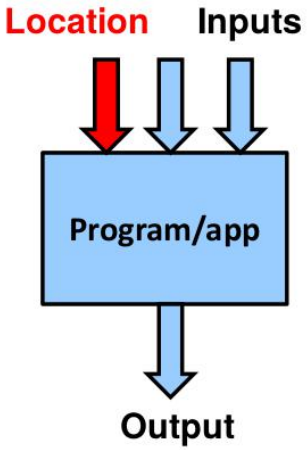
Figure 1. Improvements in laptop technology from 1990–2001.

Location-aware Computing

Example: location-awareness



Non-mobile app

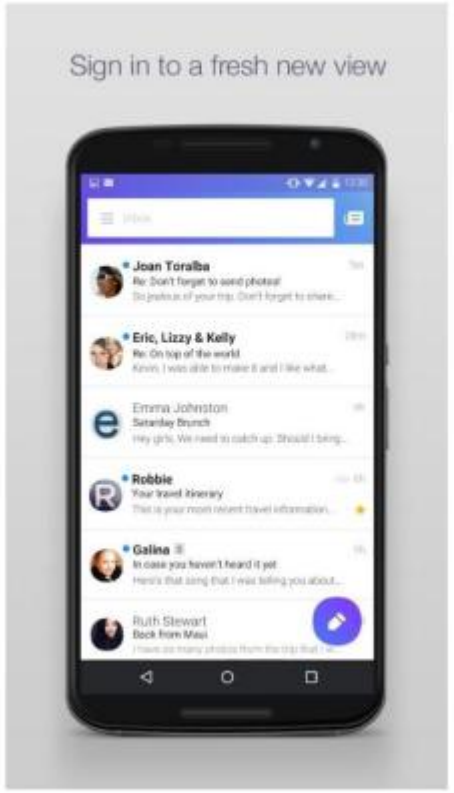


Mobile app

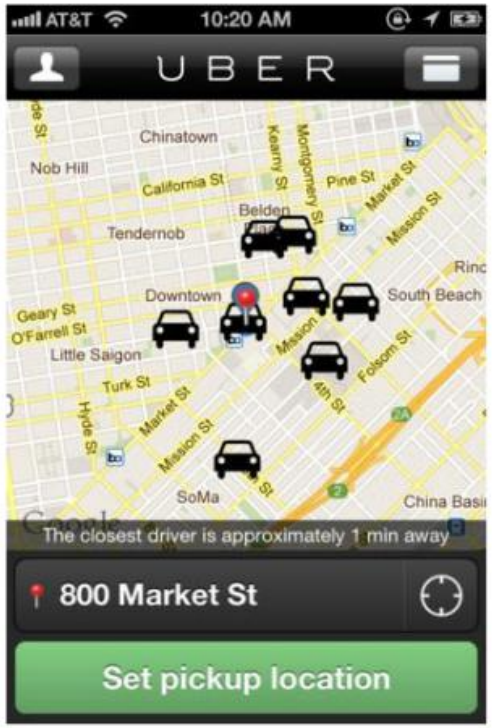
Location-aware: Location must be one of app/program's inputs
Different user location = different output (e.g. maps)
E.g. User in California gets different map from user in Boston

- What are some examples of location-aware apps?

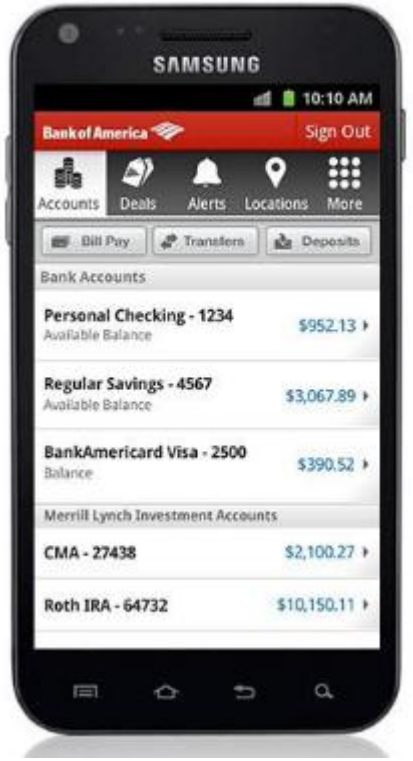
Which are location-aware apps?



Yahoo mail



uber



BoA

Notable: Sharing Economy Apps

- Idea: Share resource, maximize under-utilized capacity
- E.g. Uber: share car, Airbnb: Share house

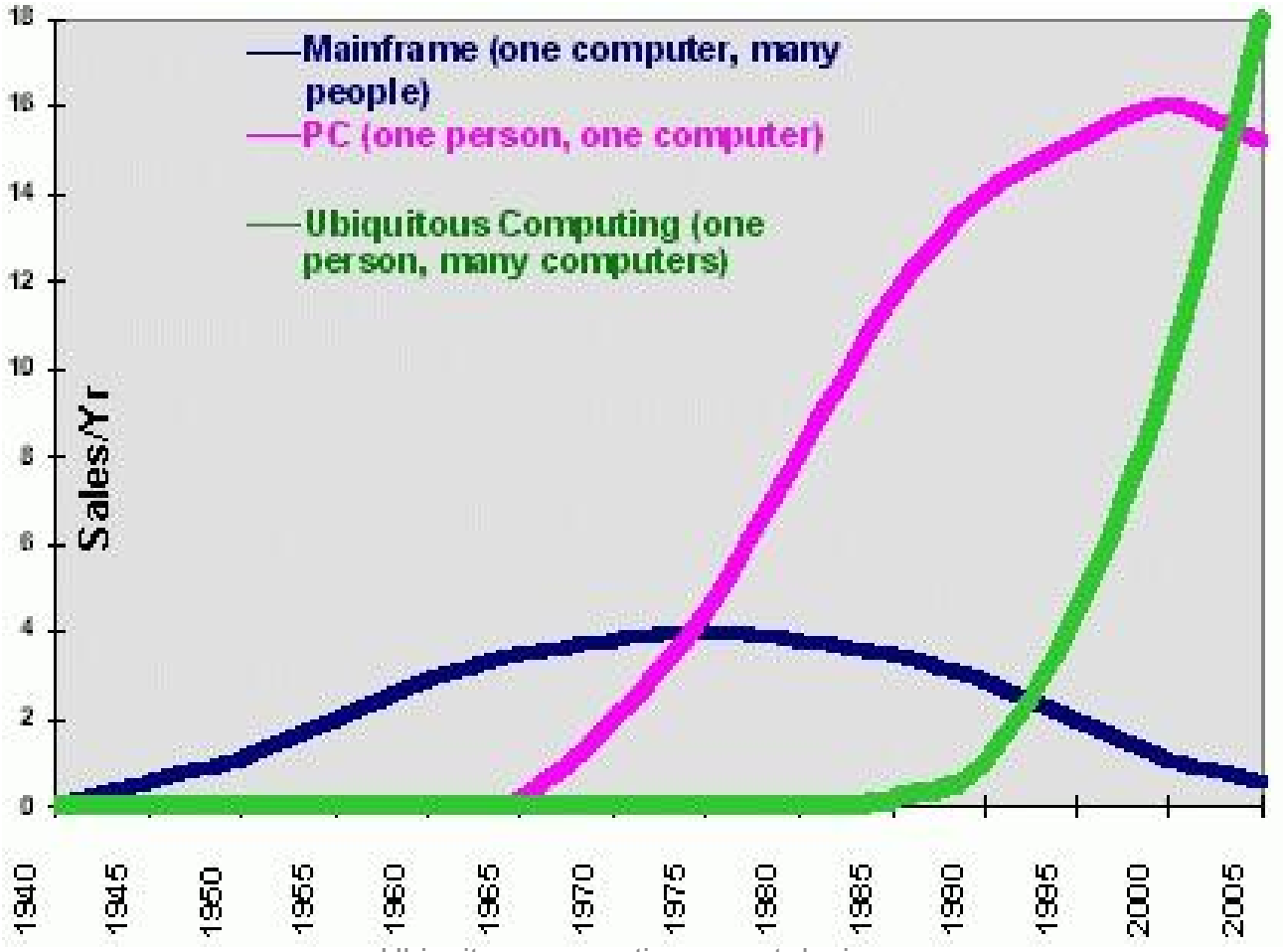
Ubiquitous Computing

Computing made to appear anytime and everywhere

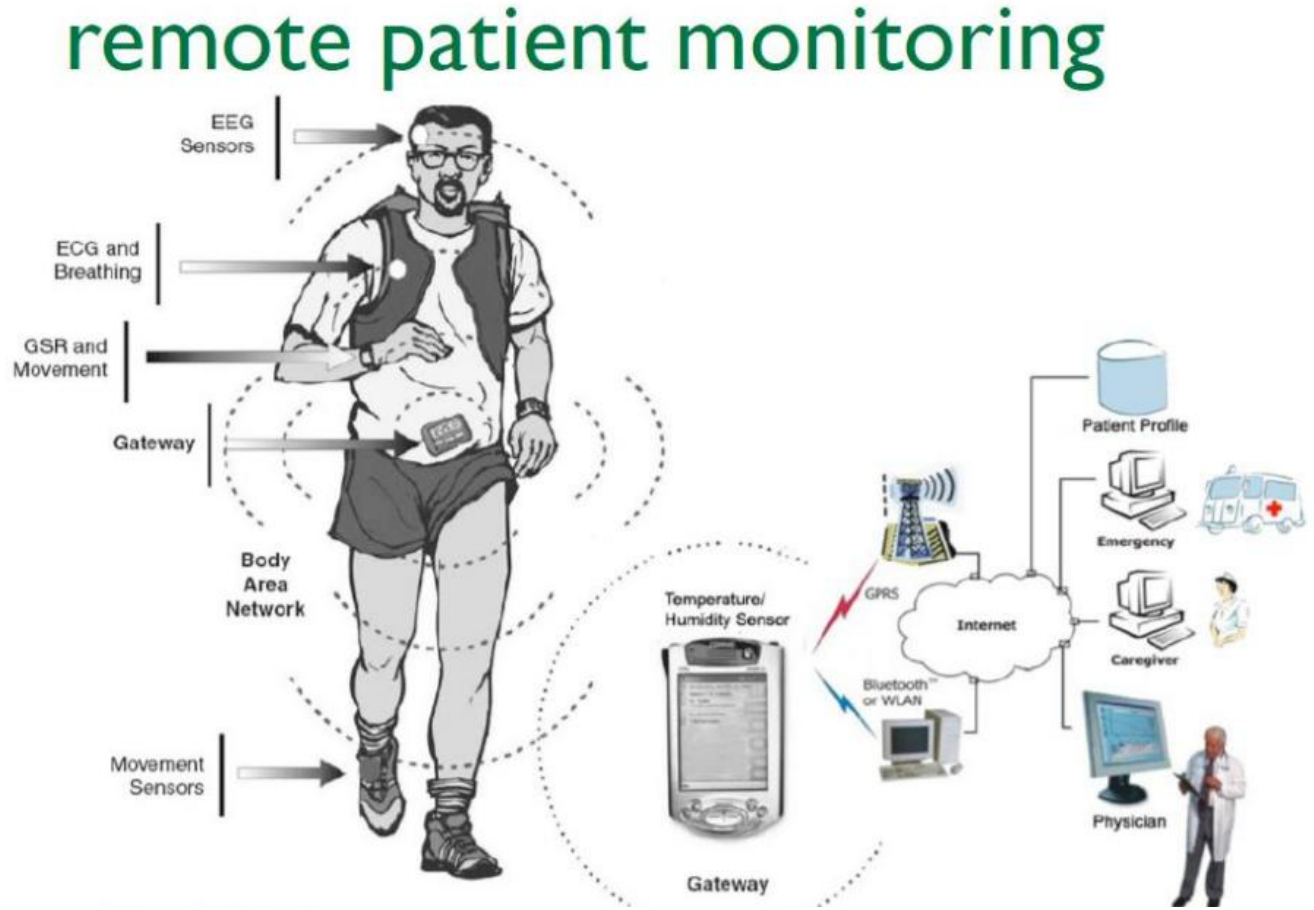
Ubiquitous Computing

- Computing is made to appear anytime and everywhere.
- In contrast to desktop computing, ubiquitous computing can occur using any device, in any location, and in any format.

Mark Weiser's 3 Waves of Computing

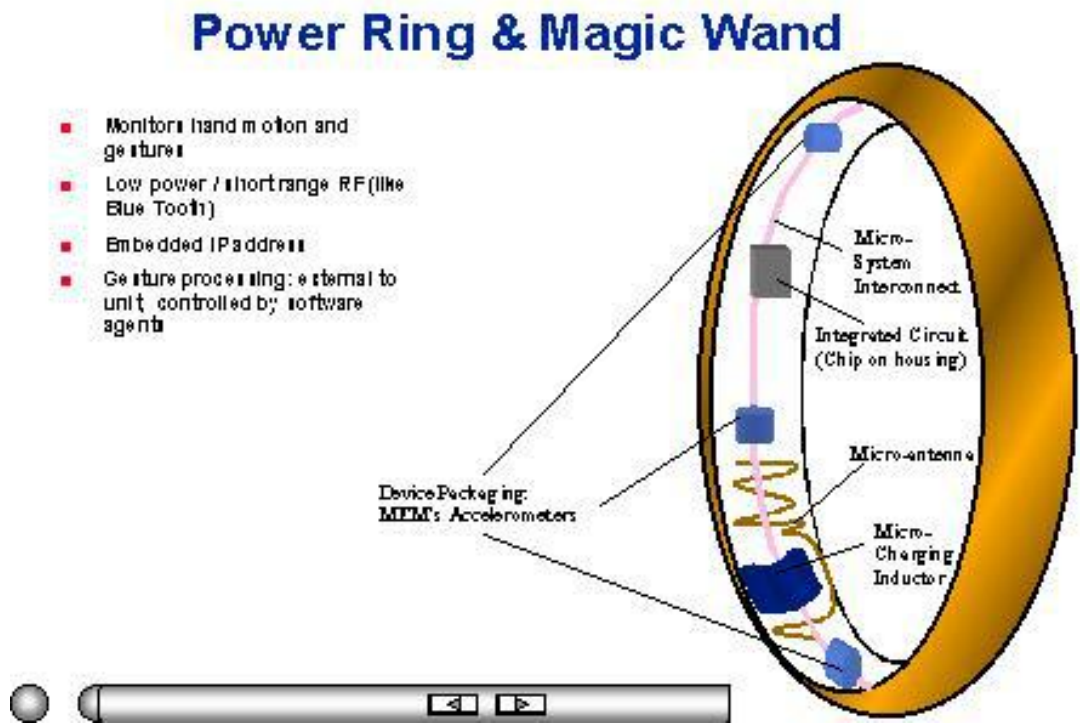


Ubiquitous Computing: Wearable sensors for Health



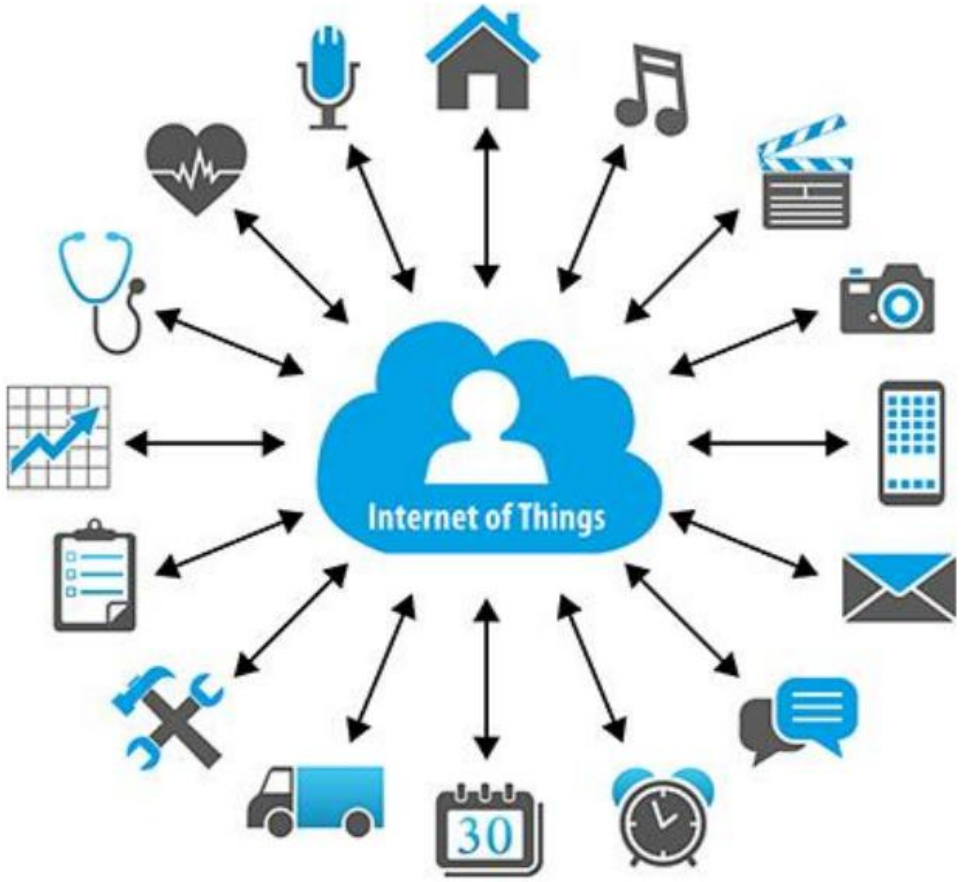
Wireless Helmet?

The Power Ring



Internet of Things (IoT)

IoT: Internet extended to connect devices



IoT: Networked Smart Things

- Smart things: Can be accessed, controlled over the network, learns users patterns

Nest Smart thermostat
- Learns owners manual settings
- Turns down heat when not around

Smart Fridge
- See groceries in fridge from anywhere

Other Smart Systems

- **Smart Homes:** Continuously monitors elders and automatically dials 911 if elder ill, fall
  - Falls kill many old people who live alone
- **Smart buildings:** Senses presence of people, ambient temperature, people flow, dynamically adjusts heating/cooling
  - Can save over 40% of energy bill
- **Smart Cities:** Real time data from Sensors embedded in street used to direct drivers to empty parking spots
  - Up to 30% of traffic jam caused by people hunting for parking