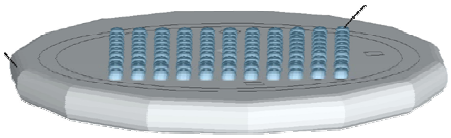
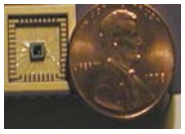
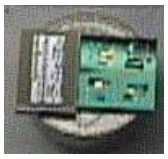
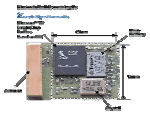


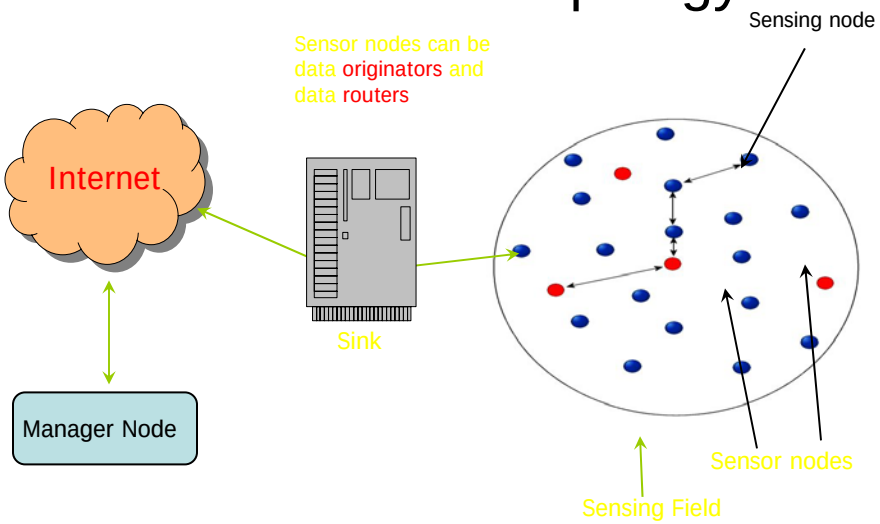


Opportunities and Challenges of Pervasive and Ubiquitous Computing in Health Care

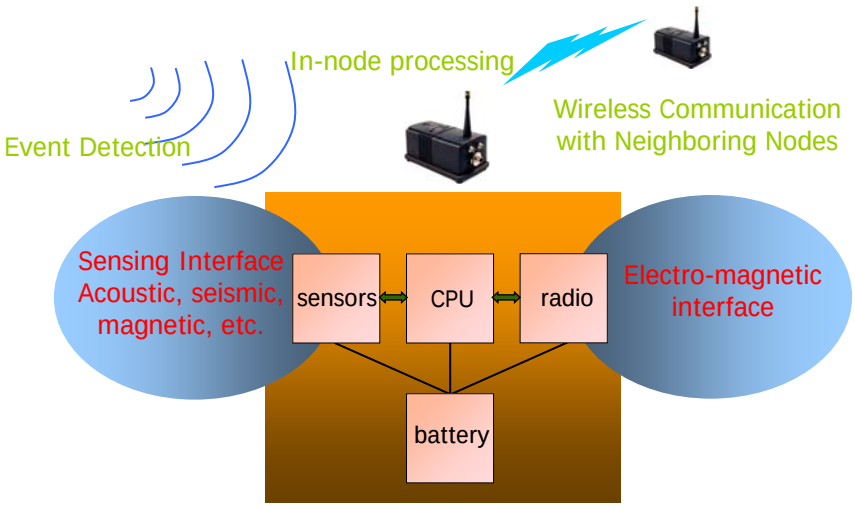




Sensor Network Topology

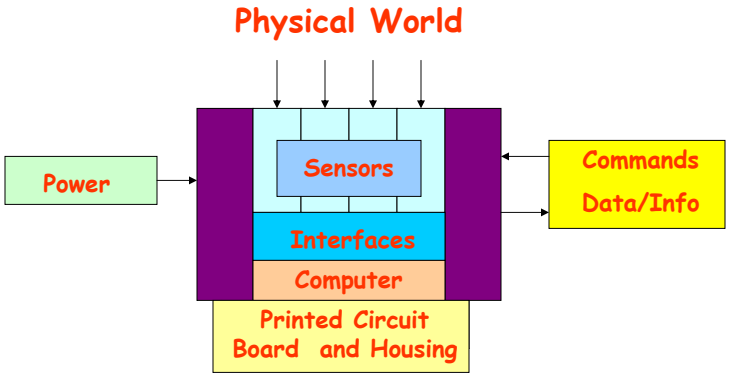


Sensors



Limited battery supply

Schematic of a Micro-Sensor



The provision of energy to operate the sensors, all electronics and the communications is essentially a limiting as well as an enabling part of wireless sensor networks

Examples of Sensor Nodes

UC Berkeley: COTS Dust

UC Berkeley: COTS Dust

UC Berkeley: Smart Dust

UCLA: WINS

Rockwell: WINS

JPL: Sensor Webs

Motes

- Smart Dust (DARPA)
  - Originally designed for military applications
- Small, autonomous computers with sensors to monitor the environment and radios to communicate with each other
  - Developed by UC Berkeley/Intel

Mote Structure and Functionalities

- Each mote contains:
  - Sensors for data acquisition
    - Temperature, humidity, light, etc.
  - Computing capabilities for data processing
  - Radio for communication
  - Power supply
- Ability to self-organize into ad hoc networks

Mote Evolution

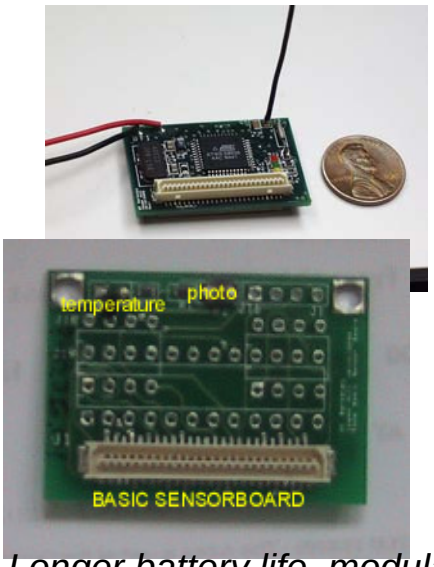
WeC

- (1999 UC Berkeley)
- Li CR2450
- 10 Kbps RFM TR 1000
- On-board sensors
  - Temperature
  - Photo (light)

Initial design suffers short battery life and little variety in sensing abilities

Rene

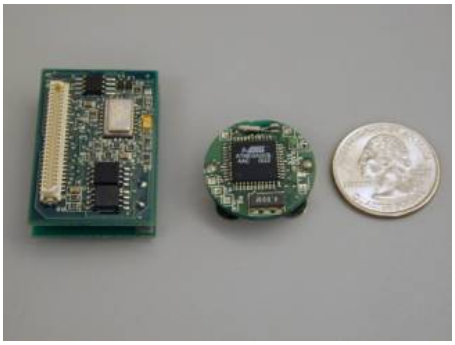
- (2000 UC Berkeley)
- 2 AA batteries
- 10 Kbps RFM TR 1000
- Detachable sensor board(s)
  - Temperature
  - Photo (light)



Longer battery life, modular sensing, but larger size

Dot

- (2001 UC Berkeley)
- Li CR2430
- 10 Kbps RFM TR 1000
- 4 pins for sensor leads
  - strain gauge
  - temp sensor
  - accelerometer
  - etc…

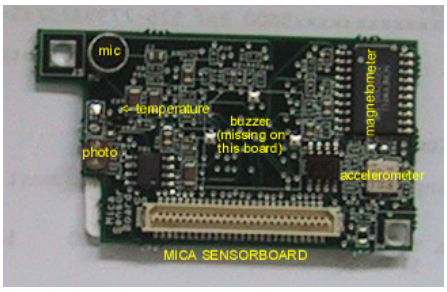


Variable sensing, smaller size,

- *Communication could be improved, and*
- *Limited number of sensors in use at one time*

Mica

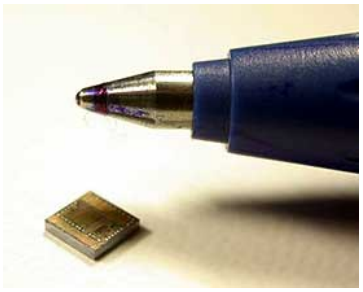
- 2002 UC Berkeley
- 2 AA batteries
- 40 Kbps RFM TR 1000
- Detachable sensor board(s)
  - Temperature
  - Photo (light)
  - Microphone/amplifier
  - Magnetometer
  - 2 axis accelerometer
  - Sounder (buzzer)



Many more sensors, faster communication, but size still limited by power requirements

Spec

- UC Berkeley 2003
- 19200 Kbps
- 30x reduction total power
- Integrated sensor
  - Temperature



Smaller and faster, uses less power, but limited sensing capabilities

Sensors for Healthcare

Typical Sensor Node Features

- A sensor node has:
  - Sensing Material
    - **Physical** – Magnetic, Light, Sound
    - **Chemical** – CO, Chemical Weapons
    - **Biological** – Bacteria, Viruses, Proteins
  - Integrated Circuitry (VLSI)
    - A-to-D converter from sensor to circuitry
  - Packaging for Environmental Safety
  - Power Supply
    - **Passive** – Solar, Vibration
    - **Active** – Battery power, RF Inductance

Biomedical Sensor Constraints

- Limited Computation and Data Storage
- Ultra Low Power Consumption
- Wireless Communication
- Continuous Operation for Chronic Applications
- Inaccessibility of Implanted Sensors

Biomedical Sensor Requirements

- Bio-Compatibility – Material Constraints
- Robustness and Fault Tolerance
- Secure Data Communications
- Regulatory Requirements
- Sensor Longevity

Combination of Features Makes Biomedical Sensor Unique!

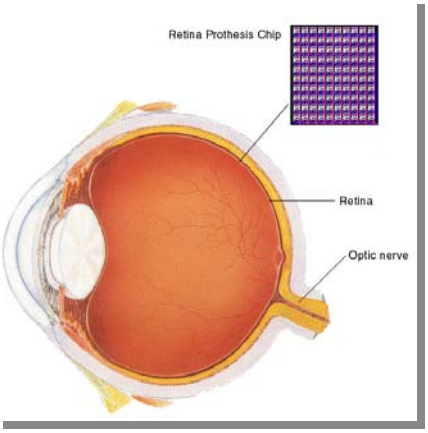
Bio-Compatibility Issues for Implanted Sensors

- Safe-Level of RF Power
  - FCC regulation: SAR < 1.6 W/kg
    - Specific Absorption Rate (SAR): Power absorbed in a unit mass of tissue.
- Bio-compatible Devices
- Minimize Heat Dissipation
  - Increased temperature can lead to tissue damage.
  - Elevated temperature increases the risk of infection.

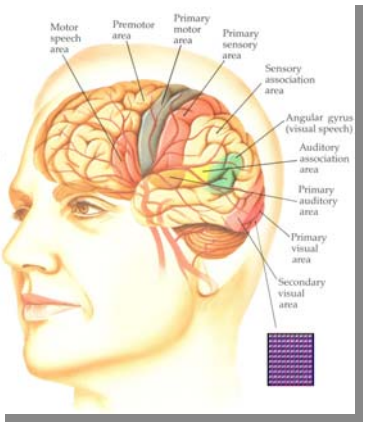
Biomedical / Medical Applications

- Chronic Diseases
  - Artificial retina
  - Cochlear implants
- Hospital Sensors
  - Monitor vital signs
  - Record anomalies
- Health Monitors
  - Glucose
  - Heart rate
  - Cancer detection

Sensor-Based Visual Prostheses

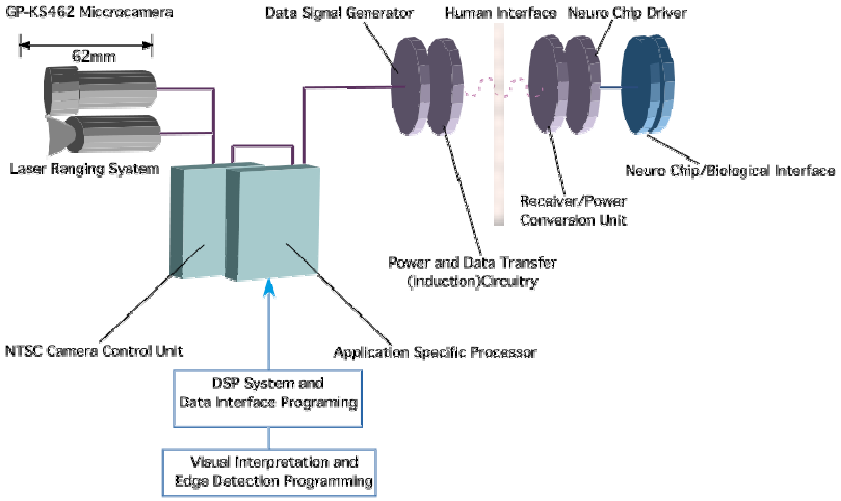


Retinal Implant

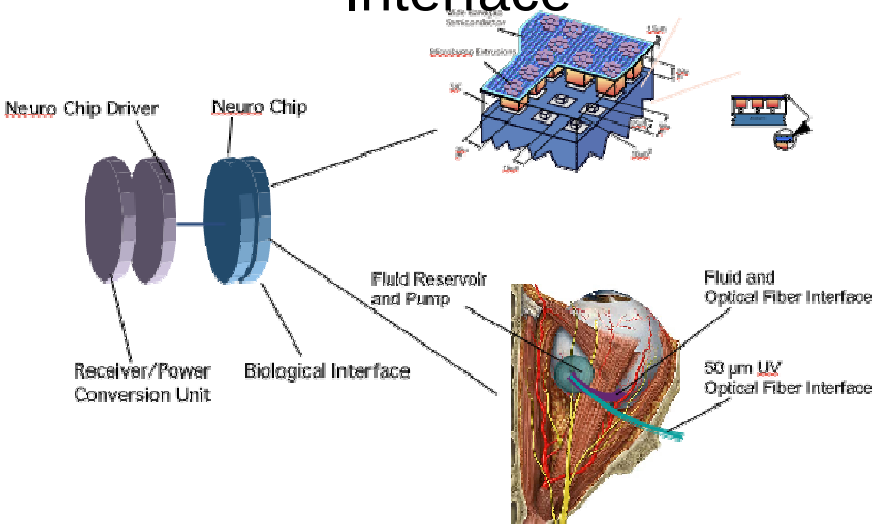


Cortical Implant

Data Processing and Communication



Smart Sensor Retinal Interface



Health Monitoring Systems

- Implanted Sensor outputs Data to PDA or Cell Phone
- Or Monitoring in the Hospital or during Surgery

Some Technical Challenges

Noisy Environments/Calibration

Sensor readings can be inaccurate.
Protocols need to recognize this.

GPS Sensor
Accurate within
2.8 meters

Relative Humidity Sensor
- Accuracy of ±5%
- ±8% at 90% Relative Humidity
- ±2% with calibration

Environmental Factors

- Wireless sensors need to operate in conditions that are not encountered by typical computing devices:
  - Rain, sleet, snow, hail, etc.
  - Wide temperature variations
    - May require separating sensor from electronics
  - High humidity
  - Saline or other corrosive substances
  - Heat dissipation

Some Impediments to Creating Future Applications

Security Issues

- Concerns about misuse and privacy
  - Privacy issues may slow adoption of sensor technology
    - HIPPA Requirements
    - Data Privacy
    - Device Privacy
  - Authentication and privacy are not always complementary objectives
  - Do not want your medical sensor hacked!!
  - Data tampering and computer viruses could be a nightmare!

Liability and Safety Concerns

- Wireless sensors could improve health care, but wireless sensors could also increase liability:
  - Use in critical applications could be difficult
    - Imagine a medical sensor fails!!
    - Or accuracy simply can not be assured
    - Limited ability to reason formally about systems
  - Healthcare providers will be reluctant about technology that increases legal exposure
    - May delay adoption

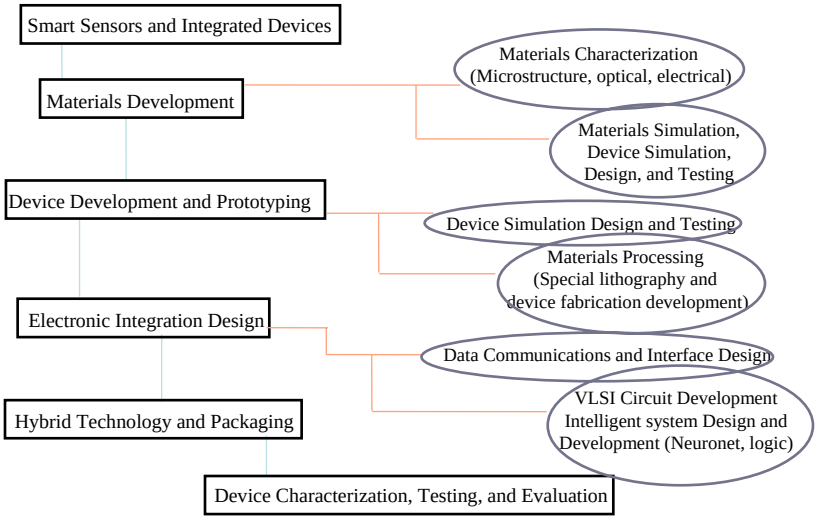
Software Engineering

- Imagine a medical sensor performing complex tasks with high levels of interaction…
  - End-user level products – easy to use
  - Software design and validation??
  - Debugging?? Software updates??
  - Meeting QoS Demands and Energy Constraints
  - Combining Multi-Sensor Data
- Example: A general health monitoring system with perhaps complex tasks based on current sensor readings

Database Design

- Applications of Databases to Pervasive Computing for Healthcare
  - Data Archiving for Monitoring Purposes
  - Historical Data for Data Mining – Research
  - Data saved for Legal Purposes
- Complicating Factors
  - Noisy Sensor Readings
  - Patient Privacy
  - Energy Efficiency
  - Scalability

Multidisciplinary Research



What will be the Top Applications of Sensors in the Healthcare Industry?

Unexpected Killer Applications

- Best applications usually follow available technology. For example,
  - PCs were available and people looked for a killer app – Visicalc.
  - The Internet was not created with these current applications in mind:
    - World Wide Web
    - E-Commerce
    - Peer-to-Peer File Sharing

Unanticipated Uses Arise

- Once technology is available, creativity leads to new applications:
  - Sims Internet world
  - E-Bay auctions of virtual property
  - Mirror for the Palm Pilot
  - Digital cameras with PC interface
- What surprising healthcare applications for wireless sensor networks?
  - Depends on sensor node technology

Summary and Conclusions

- Wireless sensor networks have a bright future
  - Many applications have been proposed
  - Potential to revolutionize the healthcare delivery system
  - Availability of sensors will lead to new and exciting applications
- A lot of research remains to be done
  - Many challenges to overcome
  - Some obstacles are technical problems – some are not
  - Allow realism to guide research efforts