Sensor Networks

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Outline

- Brief description of sensor networks
- Applications
- Sensor Networks: Details
- Sensor Networks: Challenges

Sensors

- A device that can “sense” things
  - sense = measure = instrument
- Examples:
  - Traffic Sensors
    - e.g. traffic cameras
  - Location Sensors
    - e.g. cell phones, GPS units
  - Sensors sensing environmental properties
    - e.g. temperature, humidity, light etc

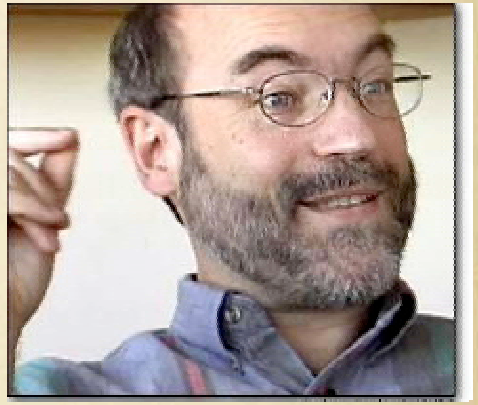
Sensor Networks

- A collection of sensing devices that can communicate with each other
- Can collectively measure or instrument a large scale phenomenon or property
  - A network of sensors instruments the San Francisco Bay Area Traffic (http://traffic.511.org/traffic_map.asp)
  - Zebranet (http://www.princeton.edu/~mrm/zebranet.html)
- Increasing number of deployments everywhere

Applications

- We will discuss a few of the applications in detail
  - Ubiquitous Computing
  - Habitat Monitoring
  - Health Care

Ubiquitous Computing



- Mark Weiser's Vision
  - *The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.*
- Sometimes called *pervasive* or *calm* computing
- http://www.hiit.fi/u/reti/interests/computer-for-21-century.pdf

Sal awakens: she smells coffee. A few minutes ago her alarm clock, alerted by her restless rolling before waking, had quietly asked "coffee?", and she had mumbled "yes." "Yes" and "no" are the only words it knows.

At breakfast Sal reads the news. She still prefers the paper form, as do most people. She spots an interesting quote from a columnist in the business section. She wipes her pen over the newspaper's name, date, section, and page number and then circles the quote. The pen sends a message to the paper, which transmits the quote to her office.

Once Sal arrives at work, the foreview [mirror] helps her to quickly find a parking spot. As she walks into the building the machines in her office prepare to log her in, but don't complete the sequence until she actually enters her office.

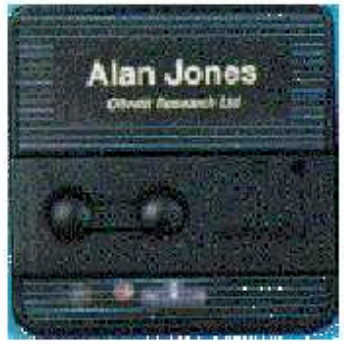
Ubiquitous Computing

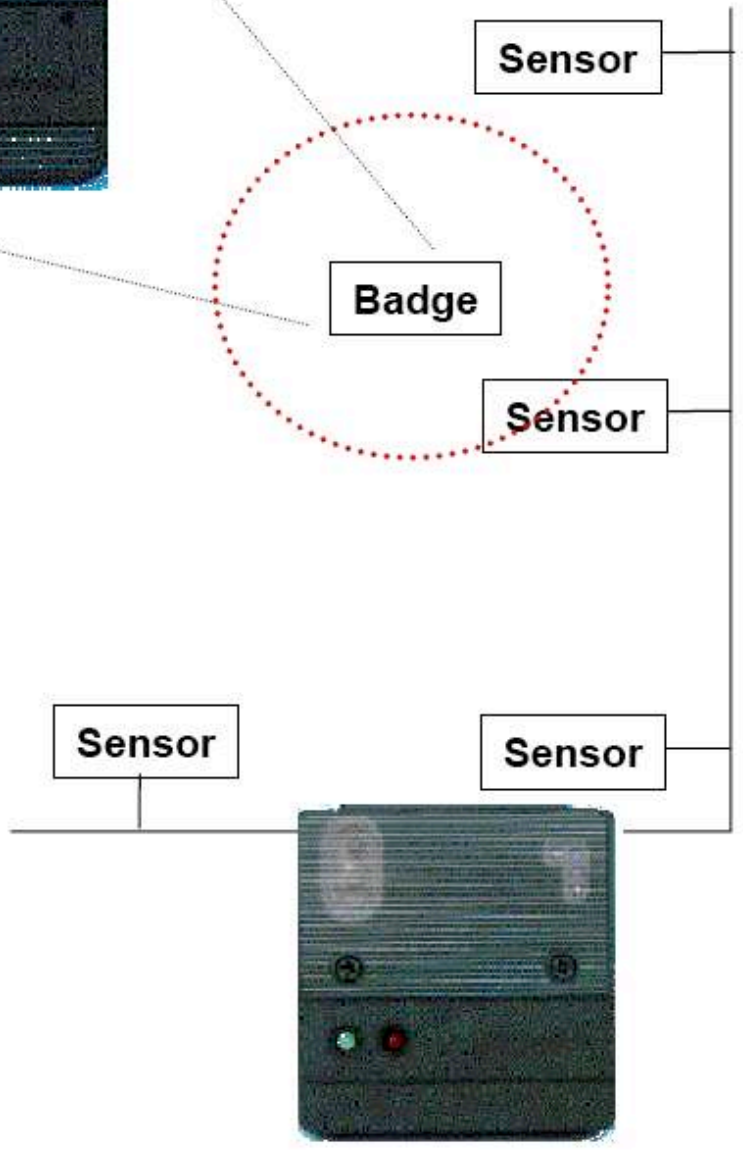
- Computing devices *pervasive* but *hidden*
  - Sense their relationship to us and each other
  - Respond appropriately to our actions
  - Communicate among each other to organize and coordinate their actions
- Need:
  - To sense a broad set of physical phenomenon
  - To observe human activity

Examples...

- .. of how sensing is used in ubicomp work

Location sensing



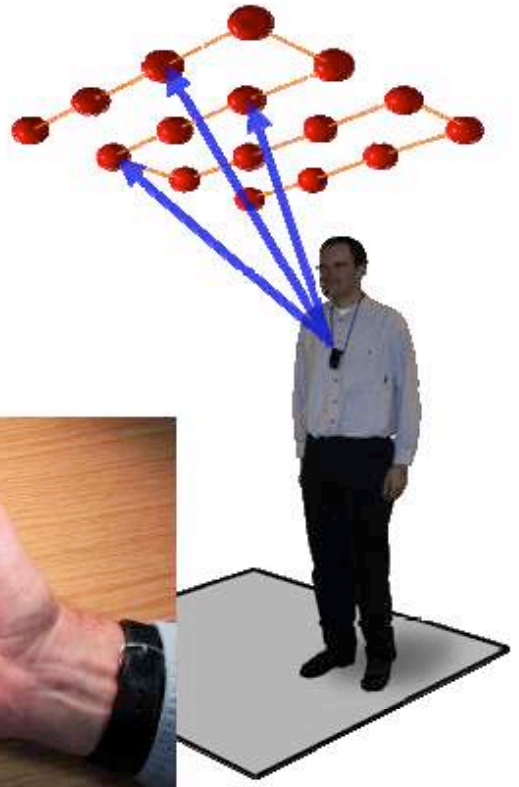


Active Badge System

- ORL, Cambridge/UK, 1989-92
- Locating people (and devices)
- Room-level accuracy
- Badges worn by people emit beacons
- Sensors with known location

- 'artificial sensing': augment phenomenon of interest (people's presence) to make it sense-able

Location sensing

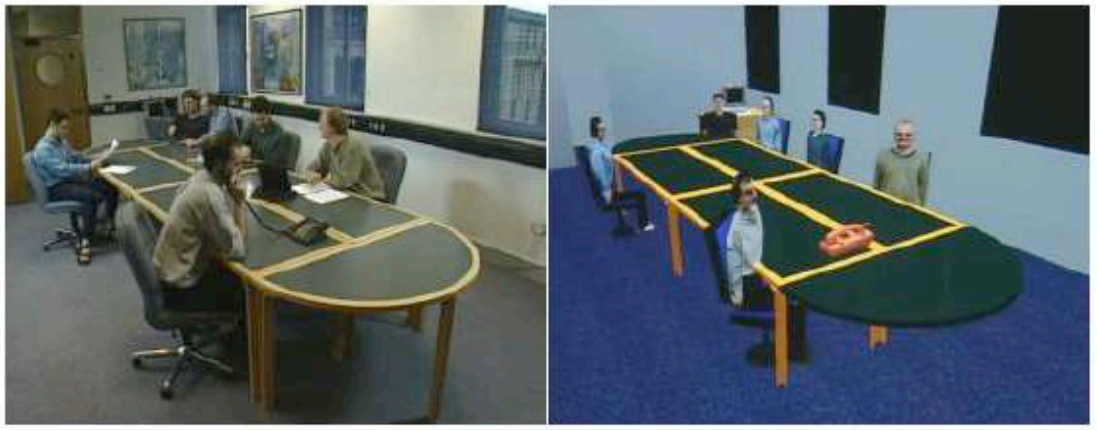


The Bat Ultrasonic Location System

- Highly accurate indoor positioning
  95% of readings within 3cm
- Bat device emits short
  pulse of ultrasound
- Ceiling mounted sensor array
- Trilateration to compute position

Sentient Computing

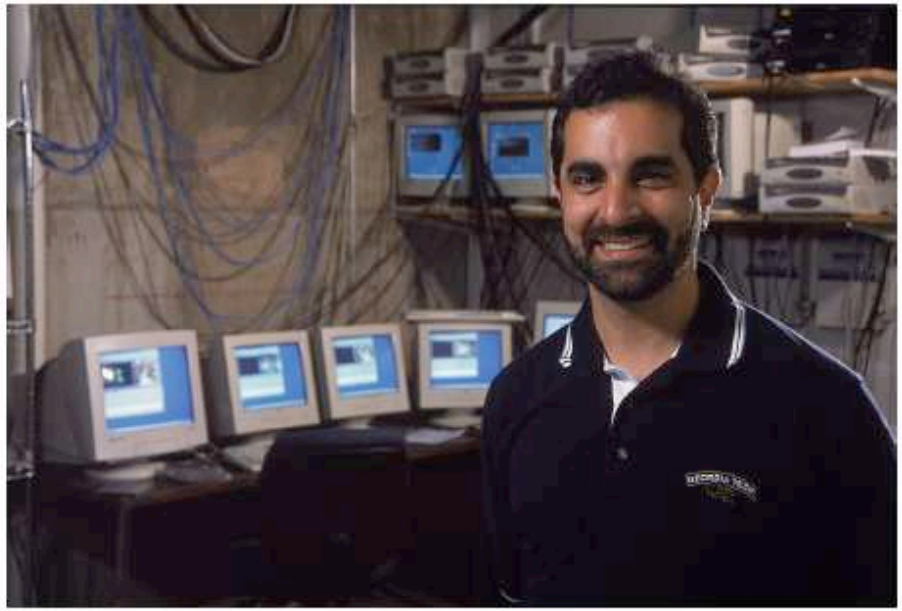
- Use sensors to construct
  model of the environment
- Shared view of the world
  between system and user



Smart Environments

The Aware Home

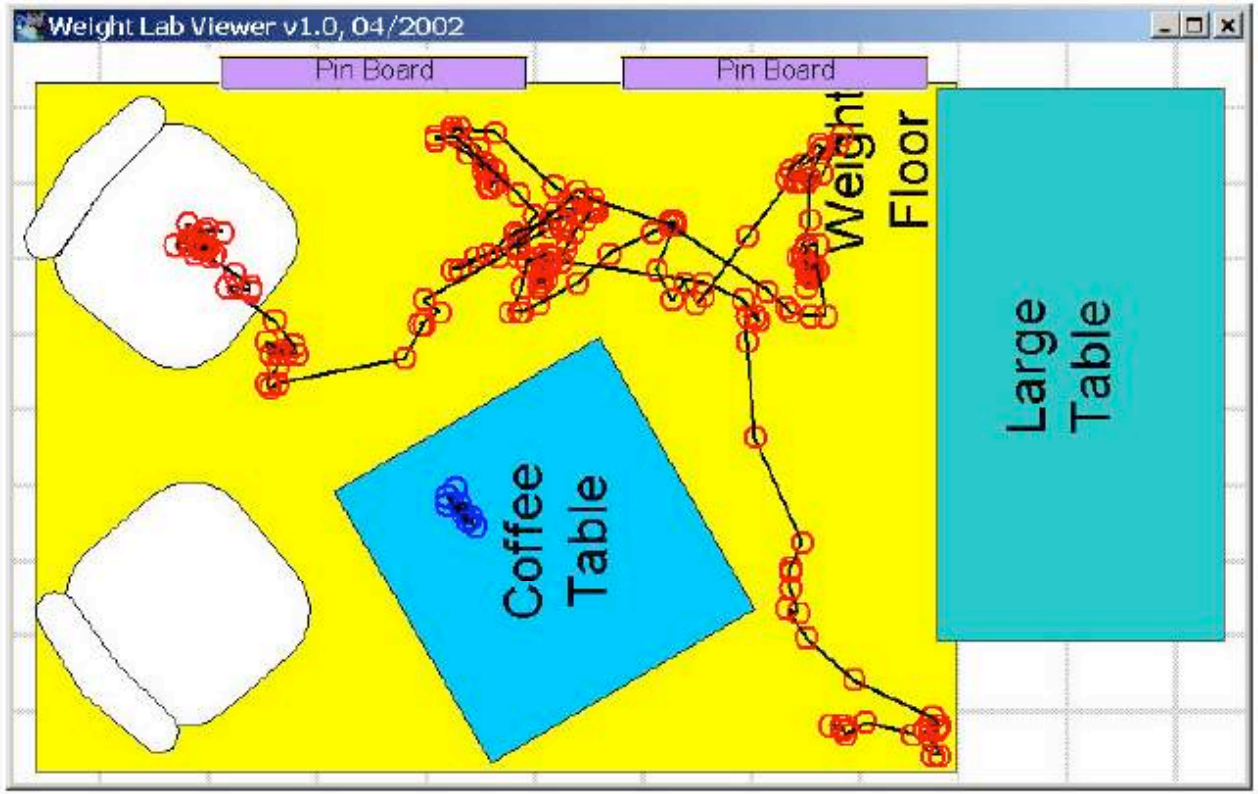
- Research initiative at GaTech
- 'A Living Lab for Ubicomp Research'
- Large-scale deployment of sensors for perception of everyday activities



Smart Environments

"Weight Lab"

- An environment in which all surfaces are load-sensitive
- Floor, tables, chairs, shelves, trays …
- Activity tracking with unobtrusive infrastructure



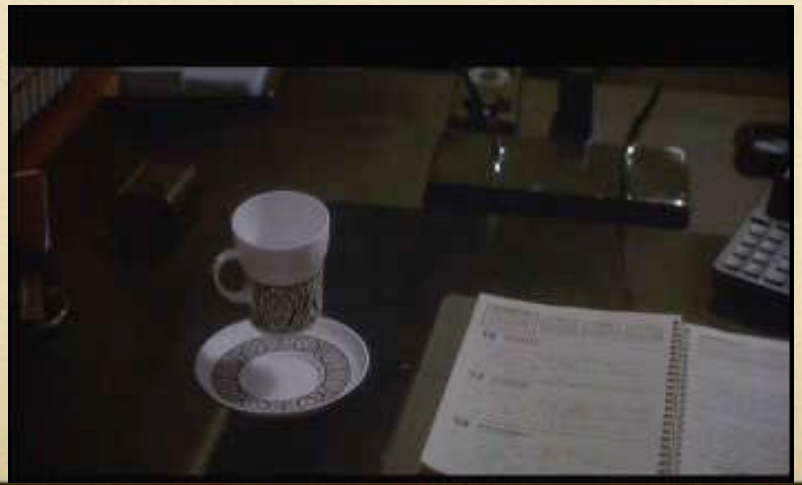
RFIDs ("Smart Labels")

- Identify objects from distance
  - small IC with RF-transponder
- Wireless energy supply
  - ~1m
  - magnetic field (induction)
- ROM or EEPROM (writeable)
  - ~100 bytes
- 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!)

Activity Inferencing

- Intel Seattle (http://seattleweb.intel-research.net/projects/activity/)
  - RFID Tags + iGlove
  - Can infer what you are doing
  - Think ‘invisible man’



Applications

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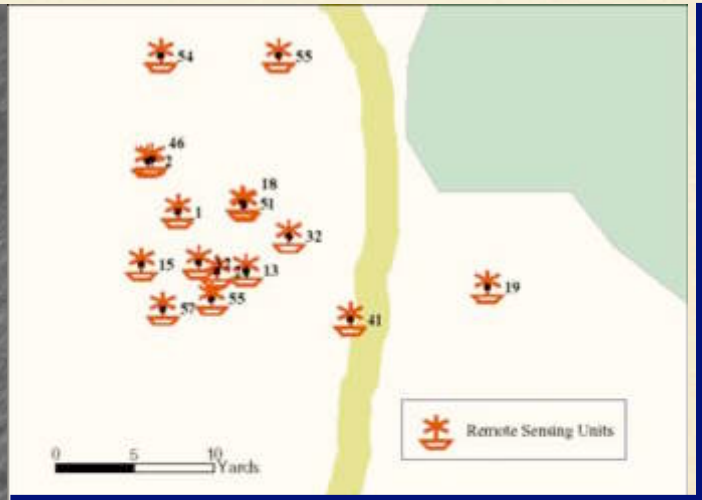
  - Habitat Monitoring
  - Health Care

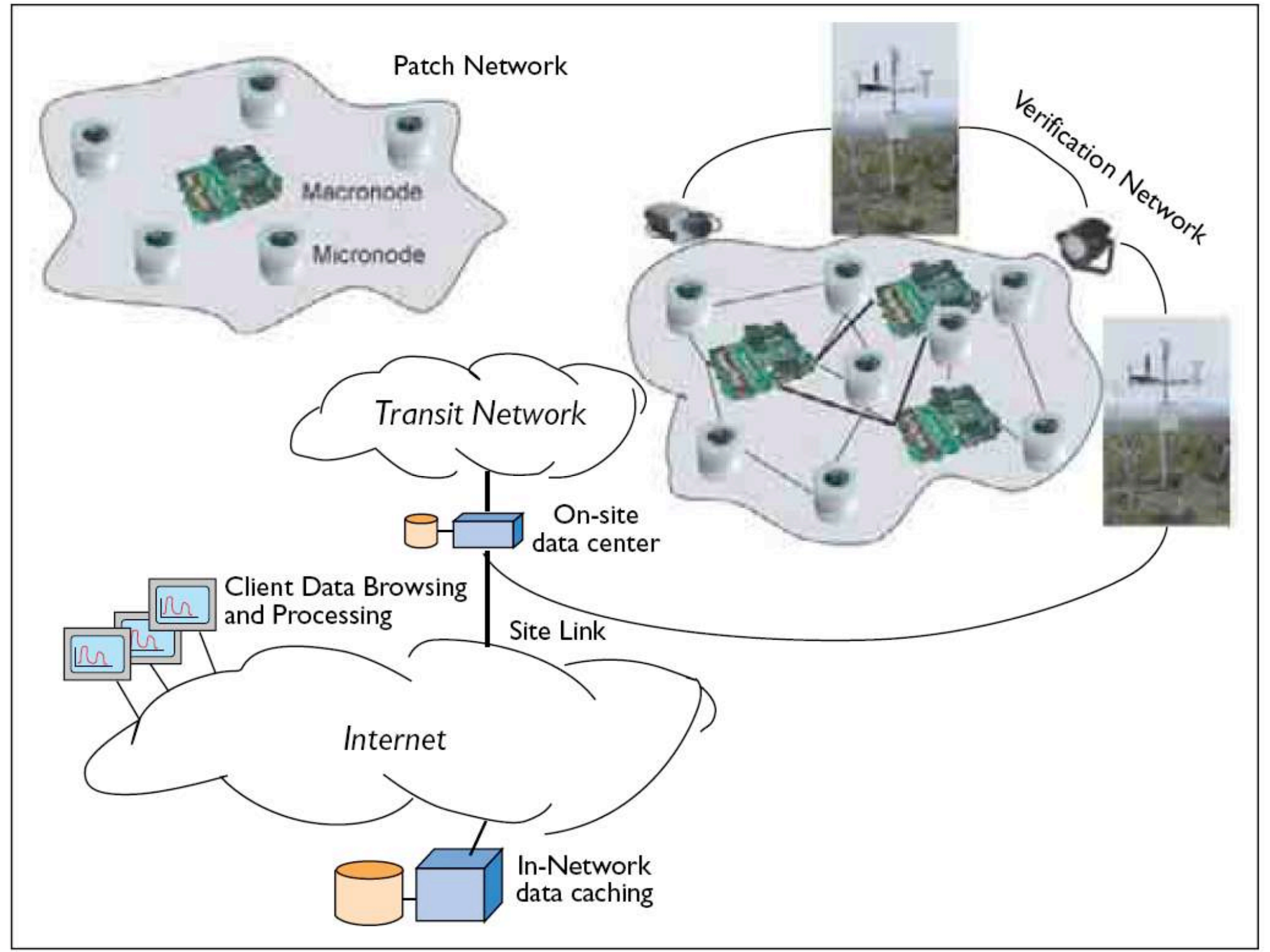
Habitat Monitoring

- Monitor microclimates around animals, birds etc
- Need remote sensing
- Can help understand the patterns of movement, the climates they like, habitat utilization etc

Habitat Monitoring

- Great Duck Island
  - Monitor Leach's Storm Petrel - An elusive seabird


54
55
46
18
51
1
32
15
13
57
55
41
19
Remote Sensing Units
0
5
10
Yards


Patch Network
Macronode
Micronode
Verification Network
Transit Network
On-site
data center
Client Data Browsing
and Processing
Site Link
Internet
In-Network
data caching


Light sensors
Protective enclosure
Battery
CPU+radio board
Temperature/humidity/
barometric pressure
Burrow
Weather

Sensors Used

4Mhz, 8 bit Atmel RISC uProc

40 kbit Radio

4 K RAM, 128 K Program Flash,

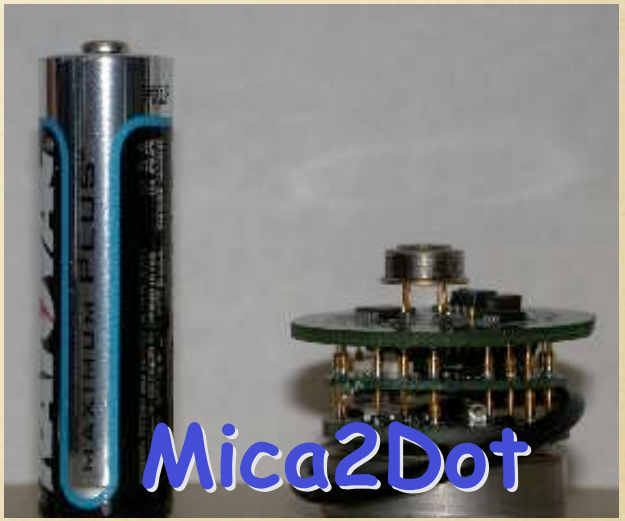
512 K Data Flash

AA battery pack

Many different types of sensors

can be attached

- temperature, humidity, light, air
- pressure, vibration, gps etc



Berkeley Motes

- Popular sensing devices
- Produced now by Crossbow
  - Can buy for $50 apiece
- Many more deployments already exist...

Applications

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Health Care

- Nursing Homes
  - Elite Care (http://www.elite-care.com)
  - Location sensors, vitals monitoring sensors etc
  - Personalized database to maintain history
- Hospitals
  - Patient monitoring, Doctor tracking

Health Care

- Bio-medical Sensors
  - Implanted in the body
  - e.g. glucose level, heart rate monitoring, artificial retina, cancer detectors etc etc
  - Emerging field

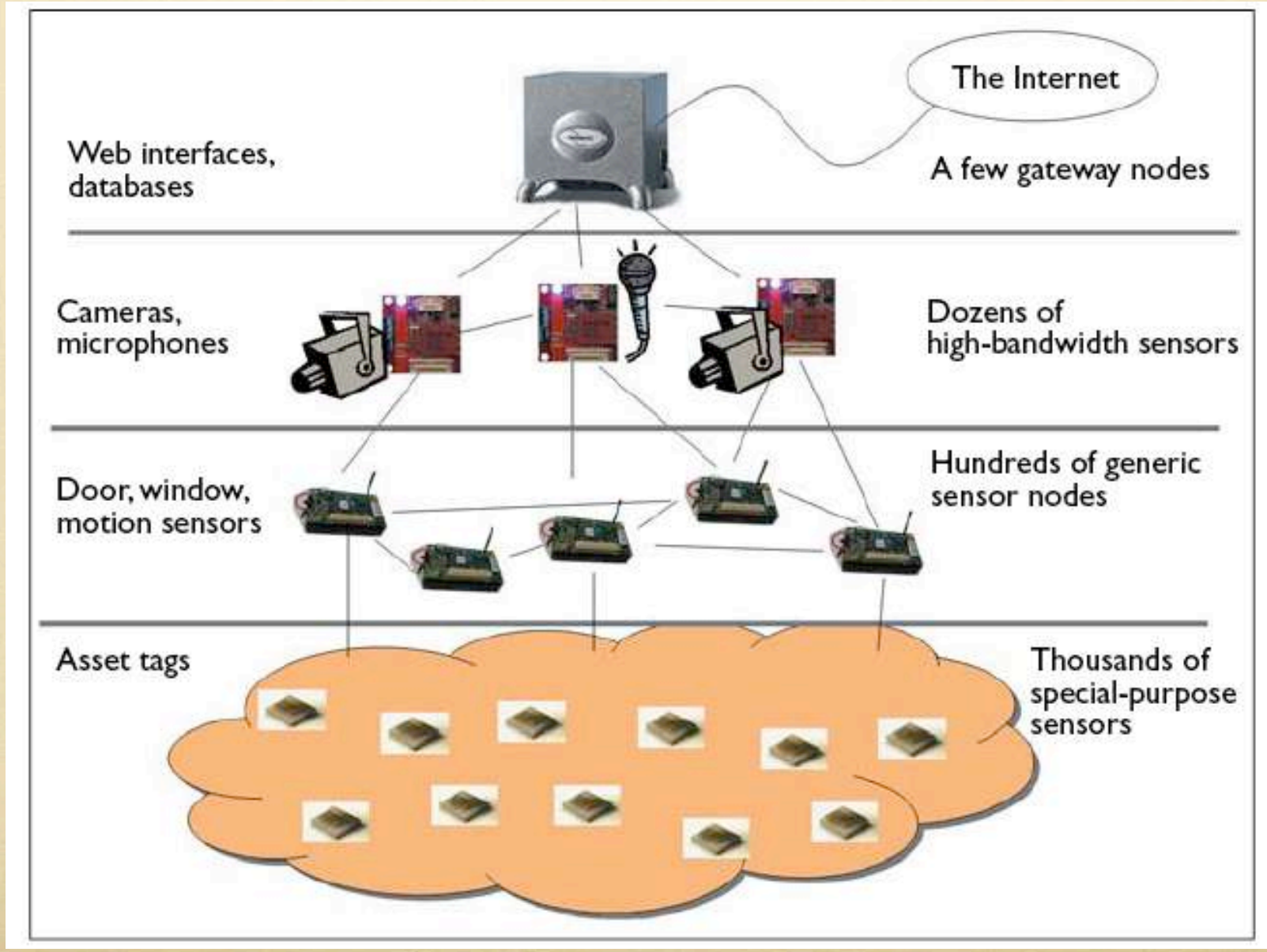
Outline

- Brief description of sensor networks
- Applications
- Sensor Networks: Platforms
- Sensor Networks: Challenges

Types of Sensor Networks

- Incredible Variety
- Especially since our broad definition of sensors
- Wired vs Wireless
  - Wireless preferred, but has energy constraints

Hierarchical Deployment

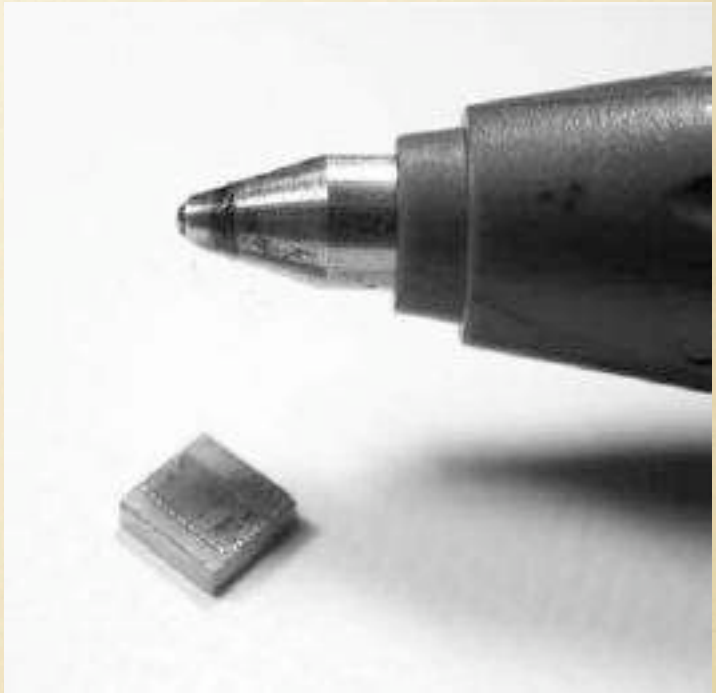


Platforms

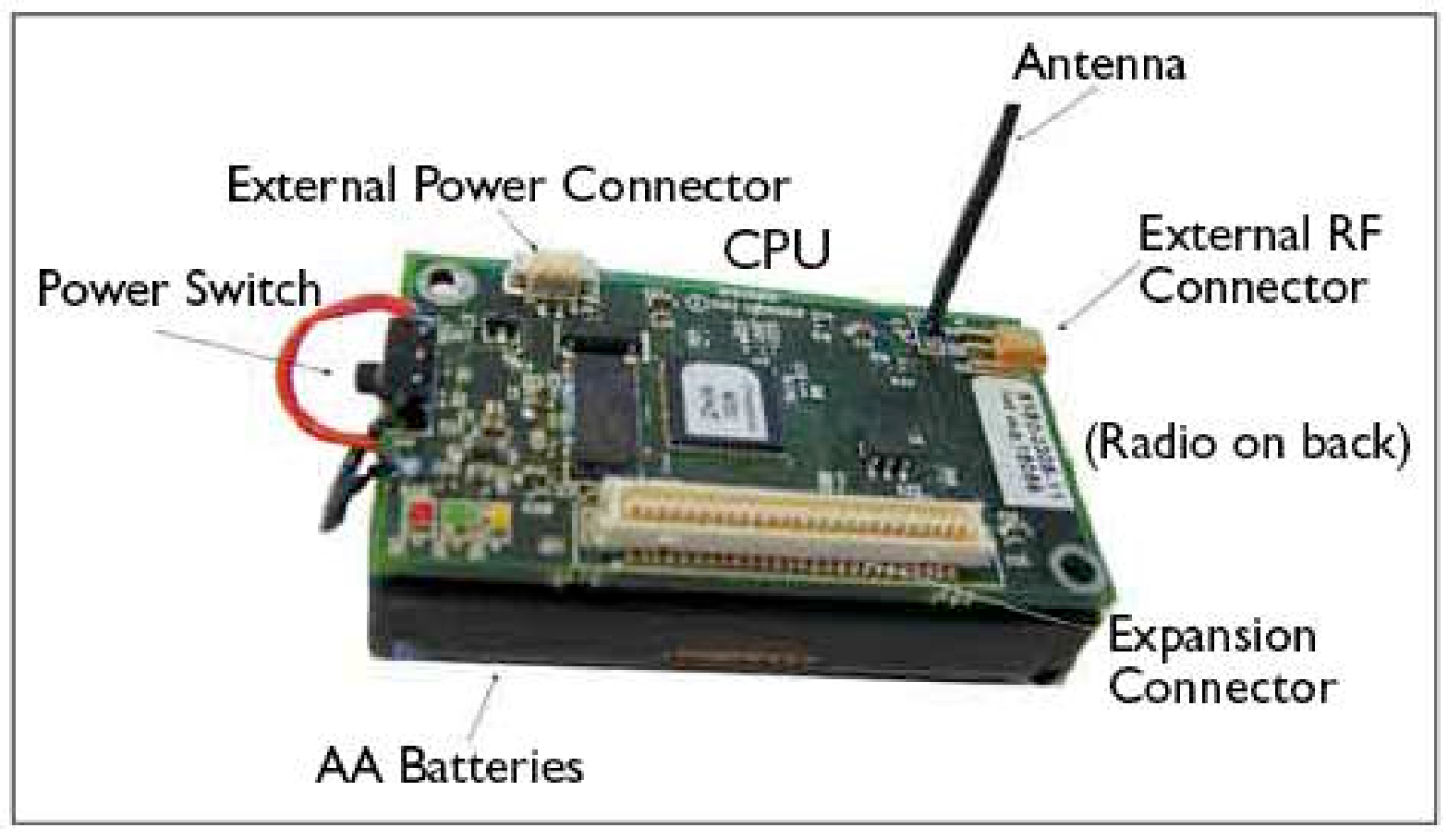
Node Type	Sample "Name" and Size	Typical Application Sensors	Radio Bandwidth (Kbps)	MIPS Flash RAM	Typical Active Energy (mW)	Typical Sleep Energy (uW)	Typical Duty Cycle (%)
Specialized sensing platform	Spec mm^3	Specialized low-bandwidth sensor or advanced RF tag	<50Kbps	<5 <0.1Mb <4Kb	1.8V*10–15mA	1.8V *1uA	0.1–0.5%
Generic sensing platform	Mote 1-10cm^3	General-purpose sensing and communications relay	<100Kbps	<10 <0.5Mb <10Kb	3V*10–15mA	3V *10uA	1–2%
High-bandwidth sensing	Imote 1-10cm^3	High-bandwidth sensing (video, acoustic, and vibration)	~500Kbps	<50 <10Mb <128Kb	3V*60mA	3V *100uA	5–10%
Gateway	Stargate >10cm^3	High-bandwidth sensing and communications aggregation Gateway node	>500Kbs–10 Mbps	<100 <32Mb <512Kb	3V*200mA	3V *10mA	>50%

Spec

- Link 1
- Link 2

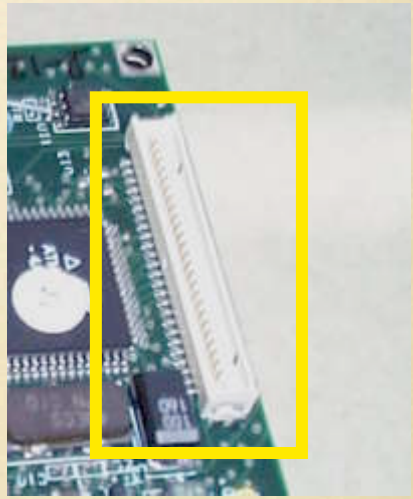


MICA2 Mote


Antenna
External Power Connector
CPU
External RF Connector
Power Switch
(Radio on back)
Expansion Connector
AA Batteries

Types of Sensors

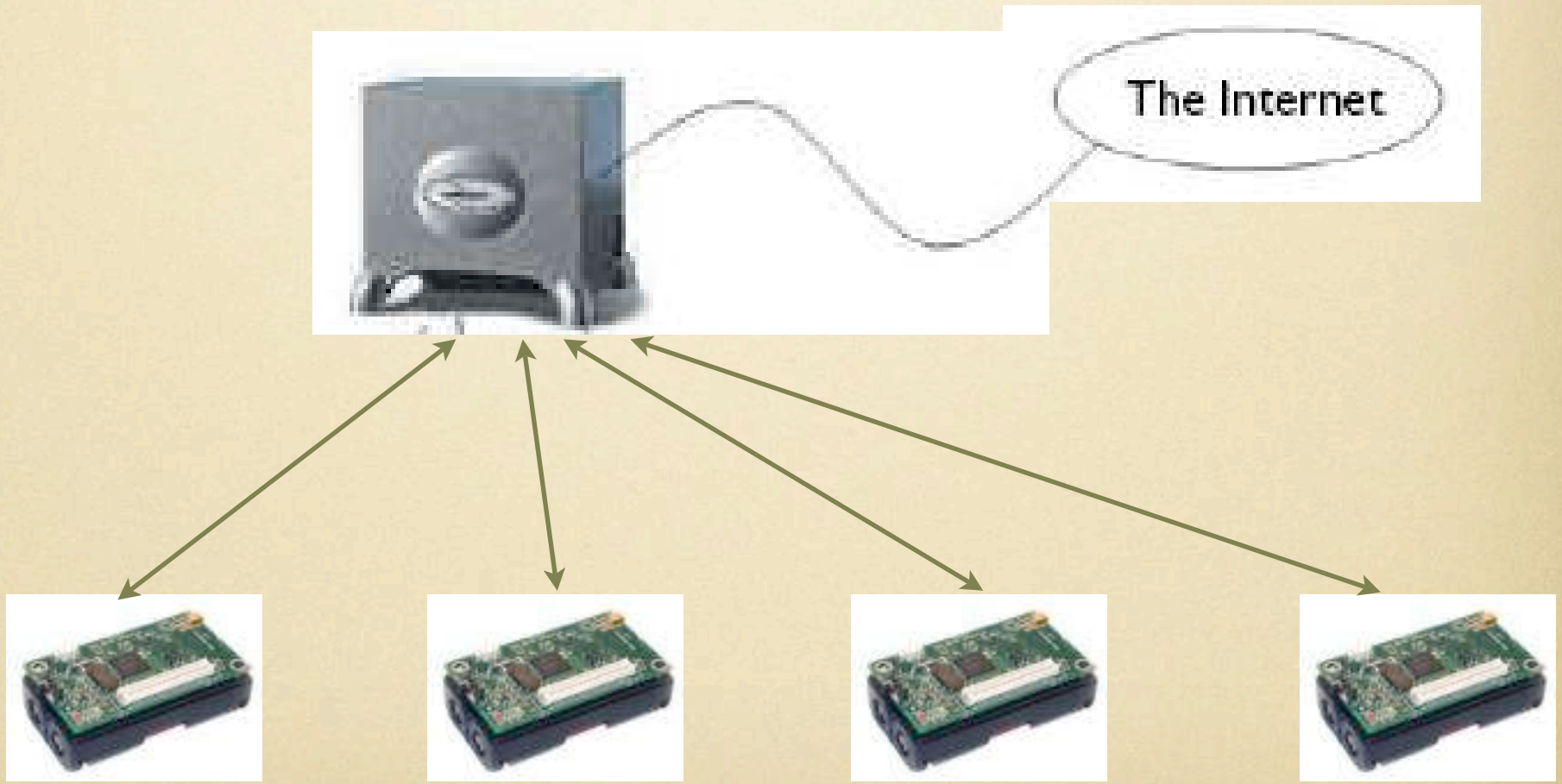
- Sensors attach via daughtercard



- Weather
  - -Temperature
  - -Light x 2 (high intensity PAR, low intensity, full spectrum)
  - -Air Pressure
  - -Humidity
- Vibration
  - -2 or 3 axis accelerometers
- Tracking
  - -Microphone (for ranging and acoustic signatures)
  - -Magnetometer
- GPS

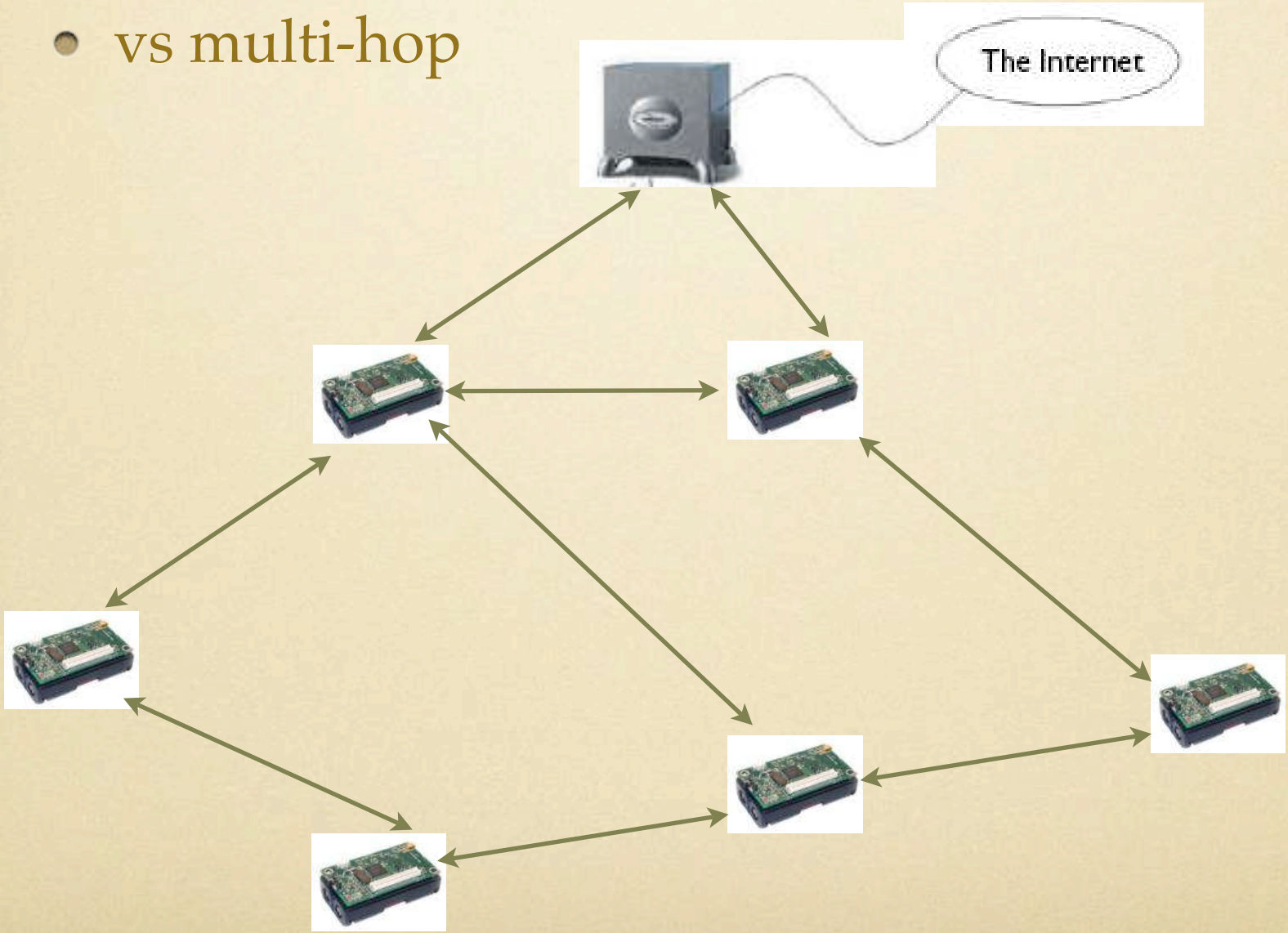
Networking

- Single hop



Networking

- vs multi-hop



Technology

- TinyOS
  - An OS that runs on the motes
  - nesC: C-like programming language
- TinyDB
- etc...

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Challenges

- Hardware Platforms
  - Motes still too big
    - But some apps need more power
  - Started with the vision of “smart dust”
  - A lot of progress in last few years...

Challenges

- Reliability
  - Deployments are in extreme conditions
  - Failures are common
    - Node failures, communication failures etc
    - Weird failures... working but not correctly

Challenges

- Programming the tiny devices
  - TinyOS/nesC help
  - Not all sensors have identical platforms
    - Too much variety right now
  - TinierOS ?
    - Some even smaller (specs, RFIDs etc)

Challenges

- Networking
  - Especially for wireless devices
  - Reliable networking is tricky
    - Especially multi-hop
  - Inherently lossy communication environment
  - Traditional internet protocols don't work

Challenges

- ENERGY
  - Battery-powered
    - Other alternative used in some cases
  - Must run unattended for months, if not years
  - Radio communication most costly
  - Battery power doesn’t obey Moore’s law

Challenges

- Data management
  - When data is missing, imprecise, interpreting it becomes tricky
  - Because of high communication costs, should push computation inside the network
  - HUGE volumes of data

Challenges

- Security and Privacy
  - Perhaps the least-looked-at, but most important challenge
  - Too much data being collected
    - This will happen whether we like it or not
    - Who controls it ? Who can see it ?

Summary

- Goal was to give you an idea of one of the exciting new things happening in computer science
- Many challenges need to be overcome before the vision becomes reality