Wireless Sensor Networks

From Research to Real-World

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Introduction

- Wireless Sensor Networks
  - Motivation
  - Overview
  - Architecture
  - Real Projects
  - State of the Art

Motivation

- Let's look at two problems with very different environments

Problem

- Monitoring wildlife
  - Record interactions and proximity
  - Desolate areas
  - Large population
  - Devices must be unobtrusive

Problem

- City Parking
  - Thousands of spots distributed throughout a city
  - How do you find one?
  - How do you find violators?
  - Instrumentation? Again, **thousands** of spots

What are the Requirements?

- Unobtrusive nodes
- Self-managing topologies
- Scalability to large numbers
- Connectivity with existing systems
- Programmability of data collection

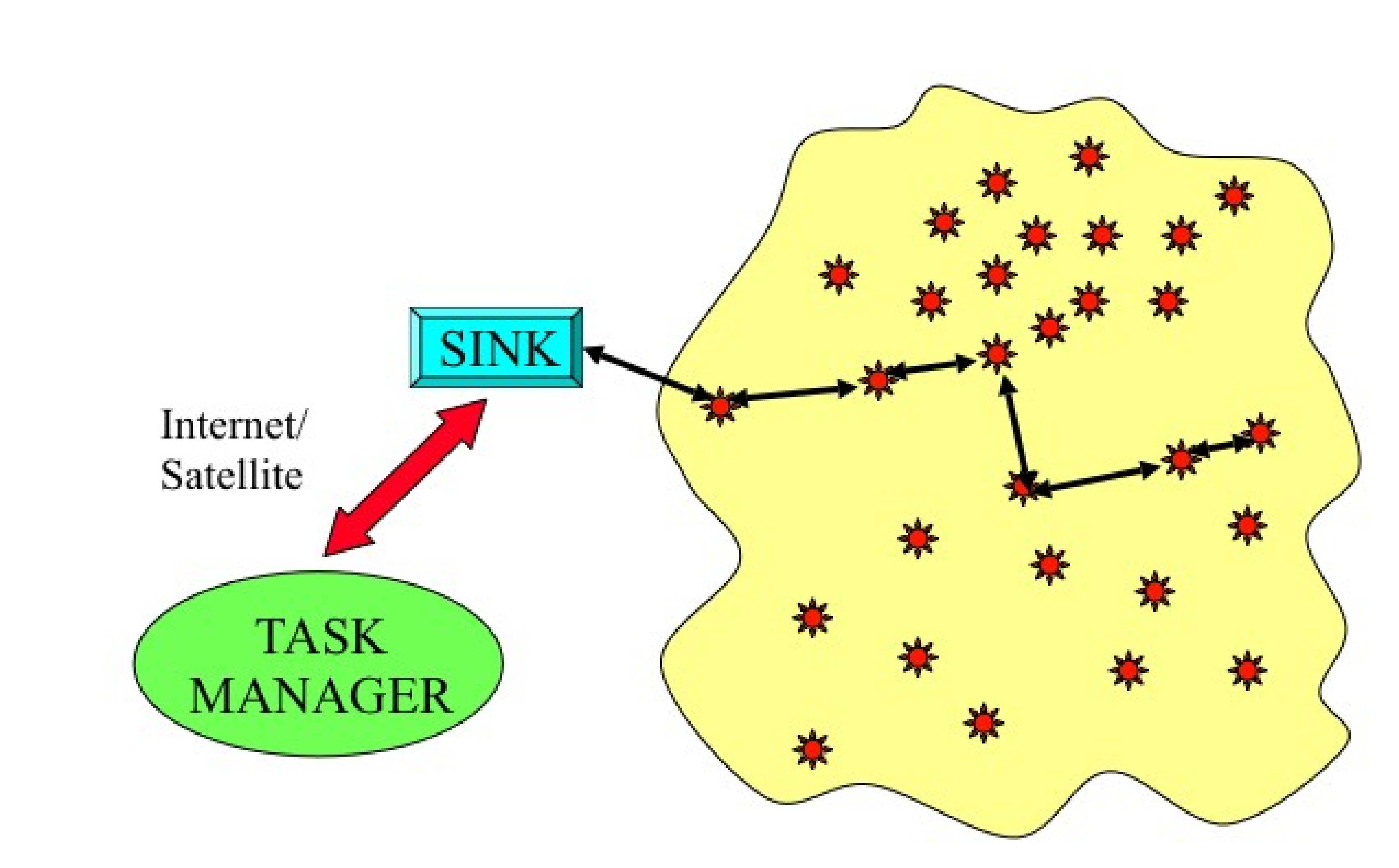
Enter Sensor Networks!

- What exactly is a Wireless Sensor Network (WSN)?
  - A collection of **sensing nodes**
- What are these wireless sensing nodes?
  - Small
  - Energy-Constrained
  - Pervasive
  - Physically aware

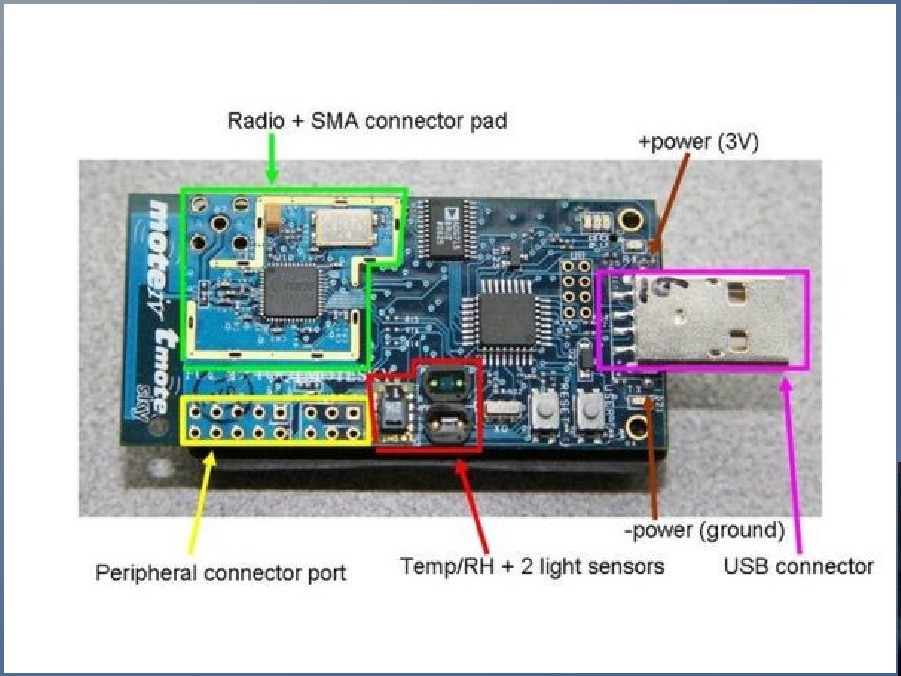
Key WSN Properties

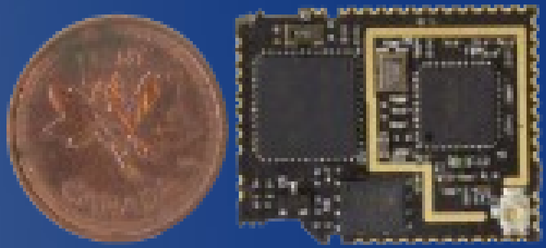
- **Small** and **Energy Efficient** and **Numerous**:
  - Deployment in challenging places
  - Collecting data everywhere
  - Inaccessible afterwards
- Numerous = low cost
- Small + energy efficient + low cost = limited resource devices
- But still **programmable**

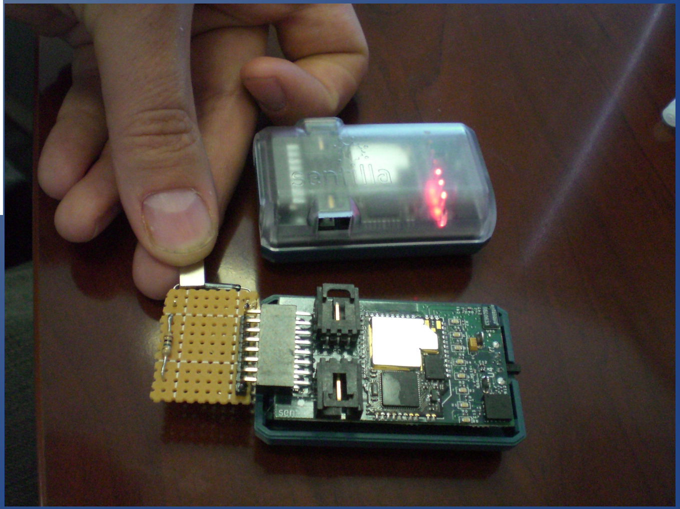
Typical WSN Topology

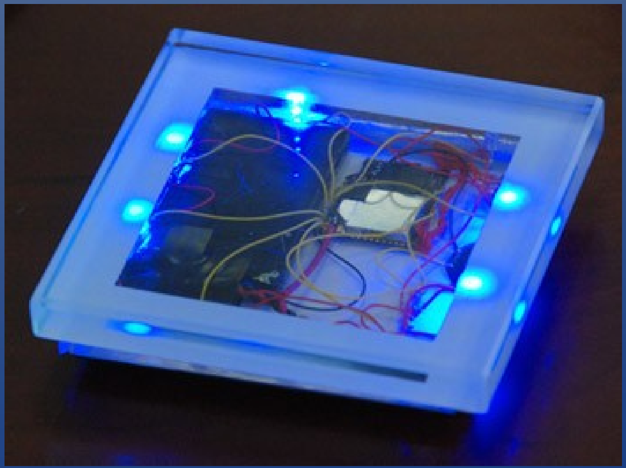


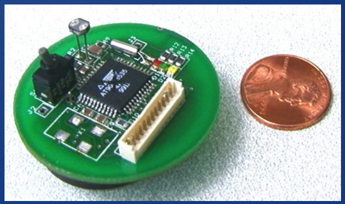
Typical WSN Nodes











Operating Systems

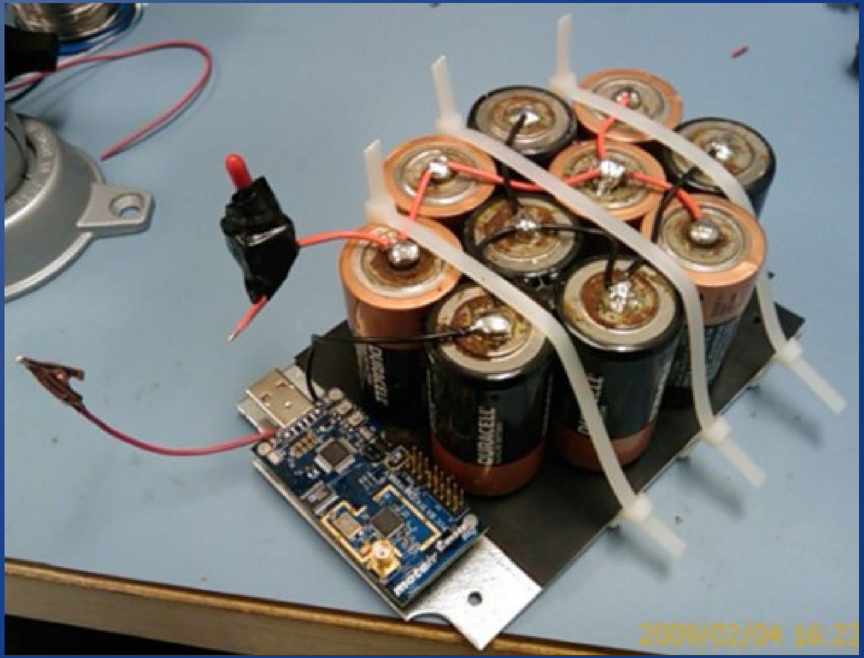
- Hardware access libraries
  - Sensors
  - Radio
  - Flash
- Very simple task scheduling
- TinyOS
  - Event driven
  - Uses nesC
- Contiki
  - Event driven
  - Multi-threaded
  - C-based
- SOS
  - Modular

Why Are WSNs Special?

- Physical sensing problem
  - Connected to the physical world
  - Location, location, location
- Limited resource nodes
- Massively distributed deployments

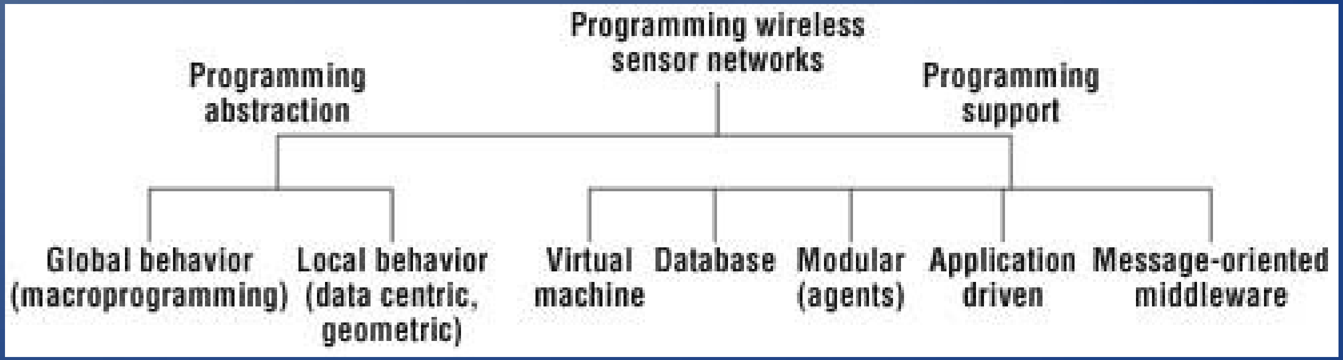
Biggest Hurdles

- Energy, energy, energy!
  - Hardware design of nodes is a huge problem
  - Wireless dominates
    - Particularly RECEIVING!



Biggest Hurdles

- Integration with existing solutions
- Programming under resource constraints
- Challenging networking characteristics



Solving the Problems

- Academia
  - Fun, challenging theoretical problems
  - Deployments that show neat data
  - Science experiments

If you can **measure** it, you can **analyze** it

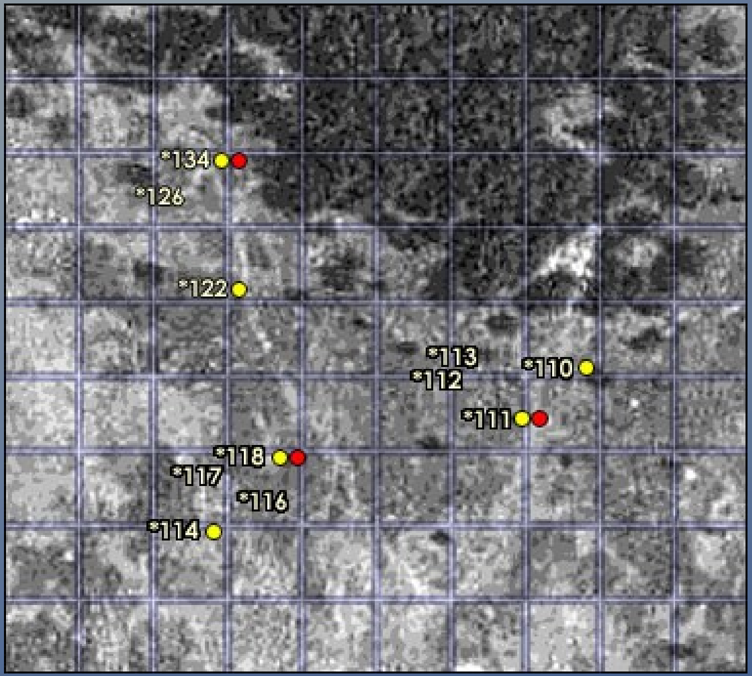
Solving the Problems

- Industry
  - Solving business problems
  - Integration with existing tech
  - Return-on-investment
  - Meeting the bottom line

If you can **measure** it, you can **manage** it

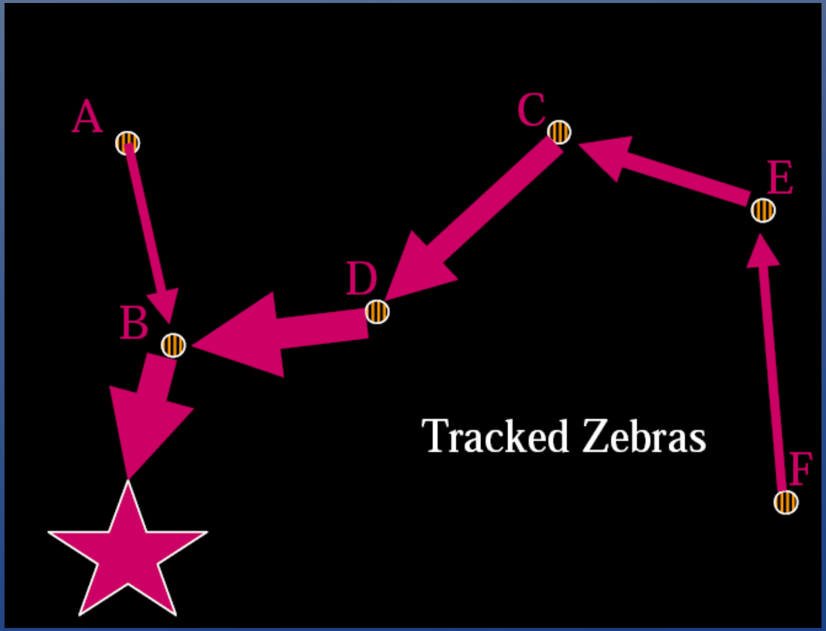
Survey: Research Projects

Great Duck Island



- Designed to “monitor the microclimates in and around nesting burrows used by the Leach's Storm Petrel.”
- Over 200 nodes
- Multi-hop network

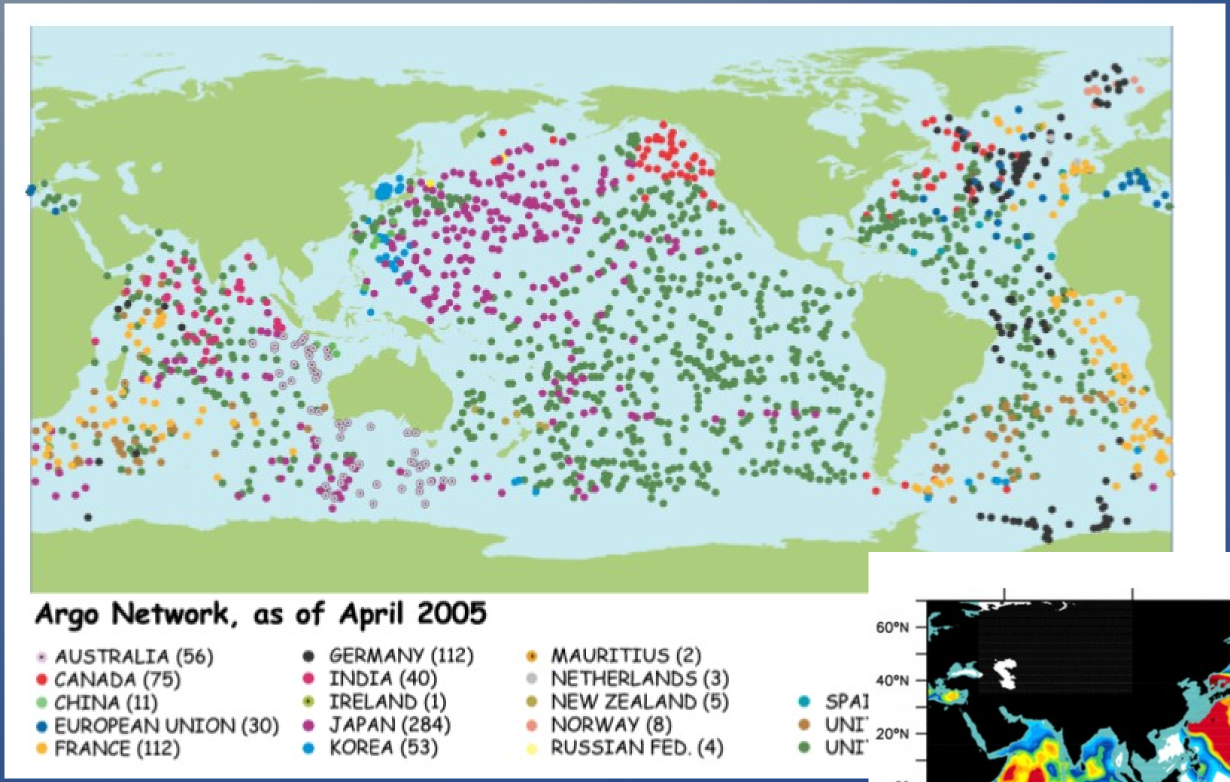
ZebraNet

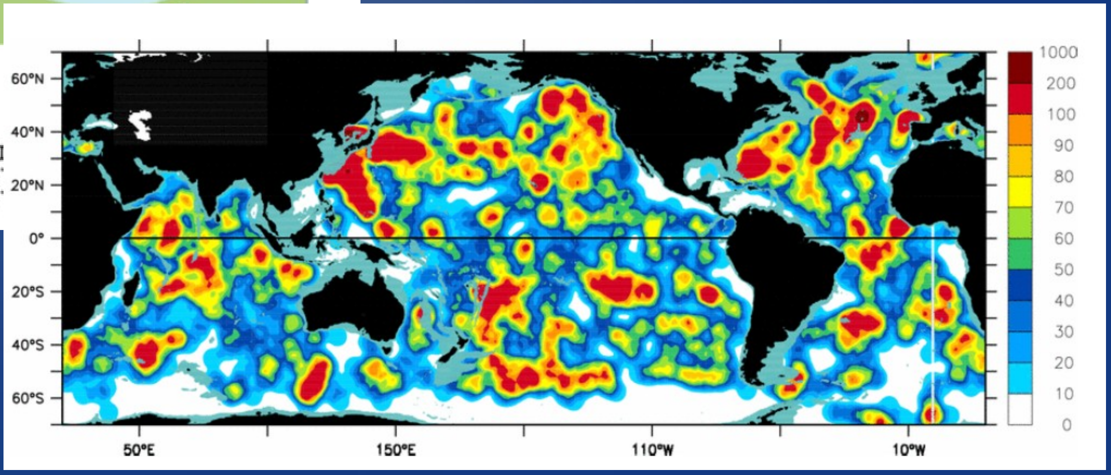


- Track wildlife in-situ
- Monitor movement, feeding, interaction patterns

ARGO

- Measure Global Seawater Salinity





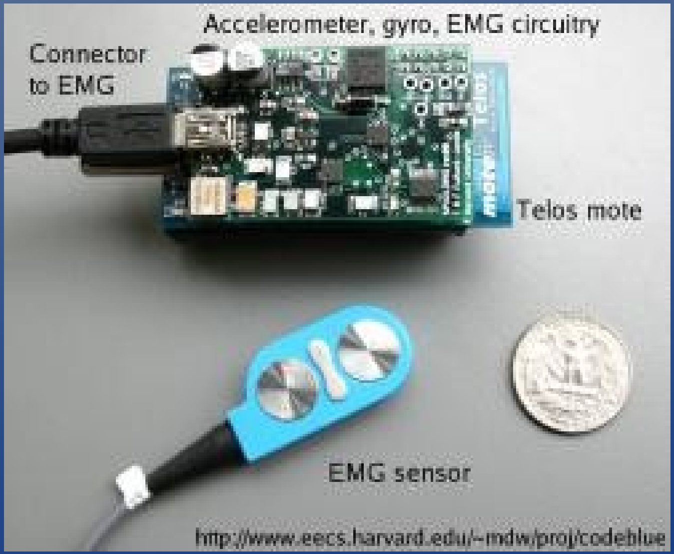
ARGO

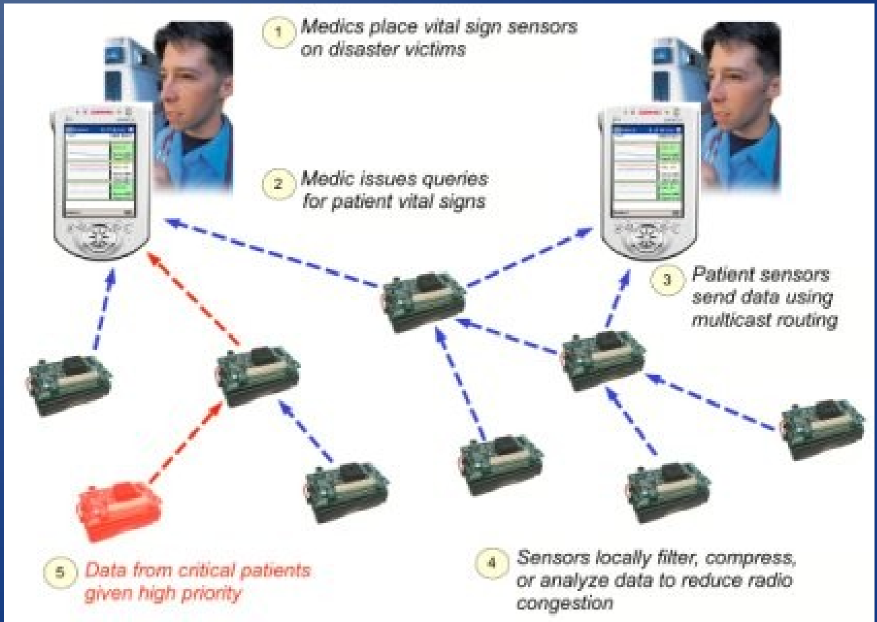
- How could this be converted into a wireless sensor network?

Survey: Industrial Projects

Codeblue

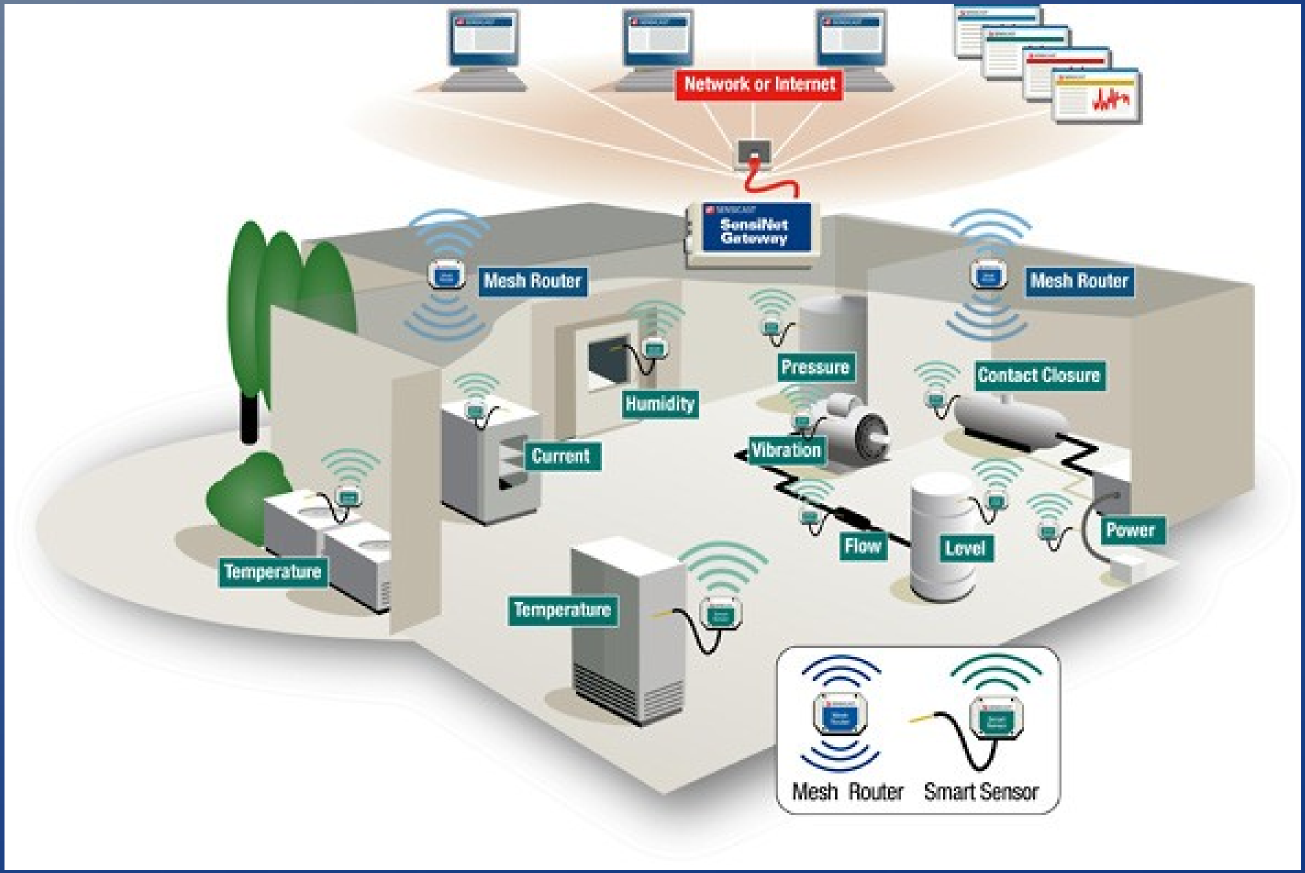
- Pre-Hospital Monitoring (triage)
- In-Hospital Monitoring
- Disaster Response
- Rehabilitation Assistance





SensiNet

- Industrial Process Monitoring
- Detect ineffeciencies to lower costs



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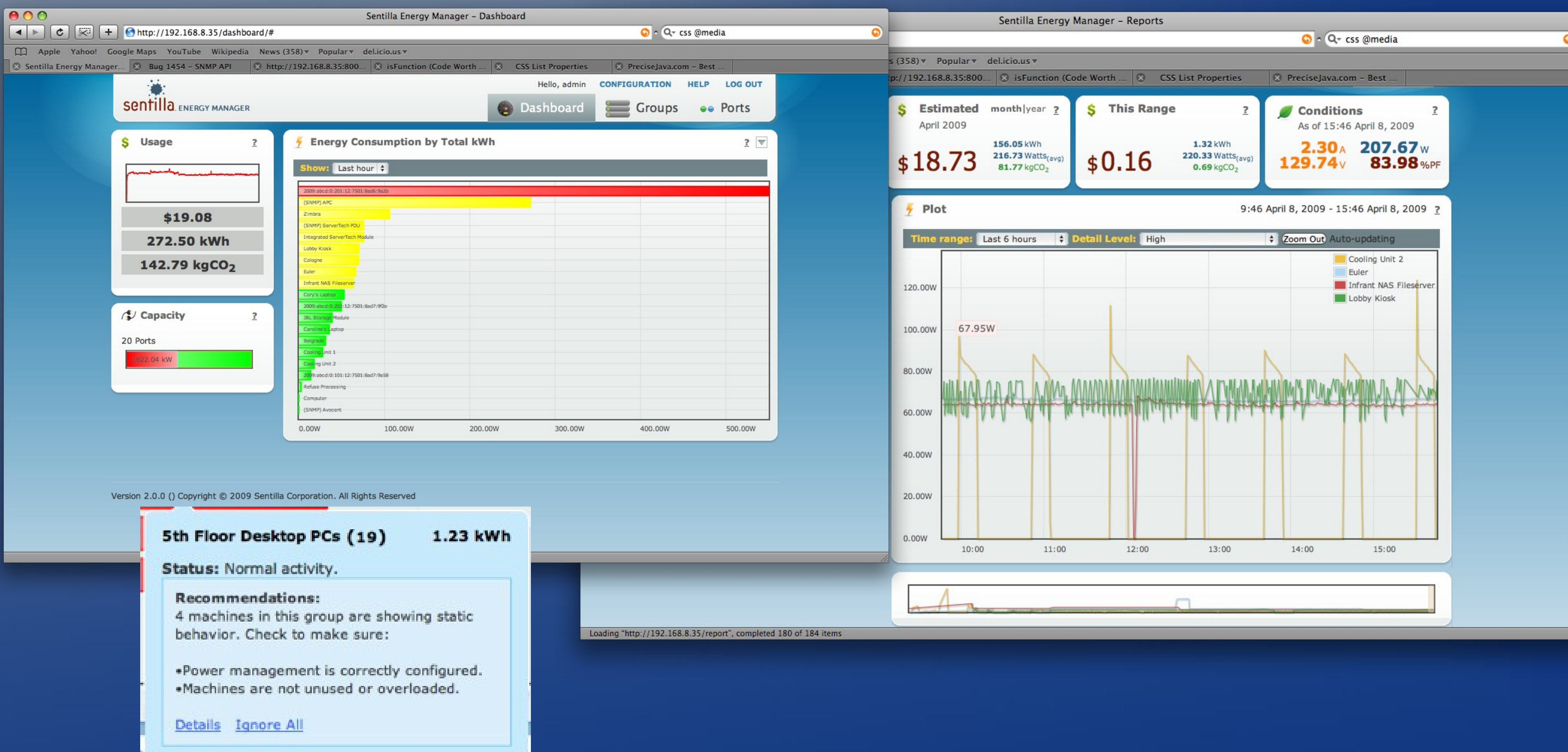
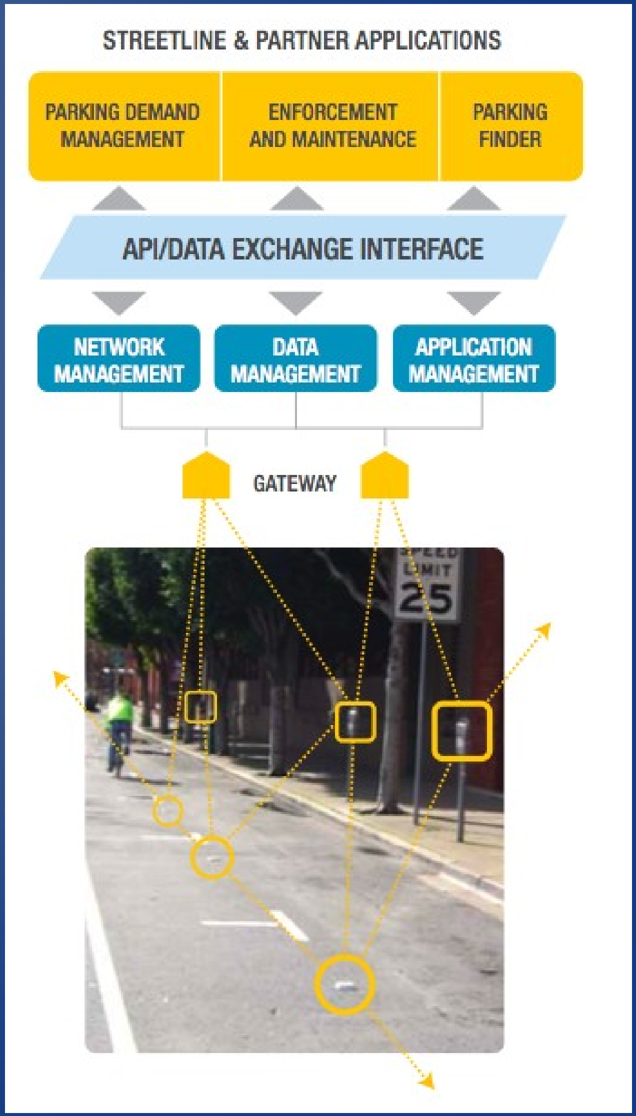
- Monitor energy usage in datacenters
- Detect opportunities for decreased consumption



Streetline

- Parking Management
- Traffic Monitoring



State of the Art

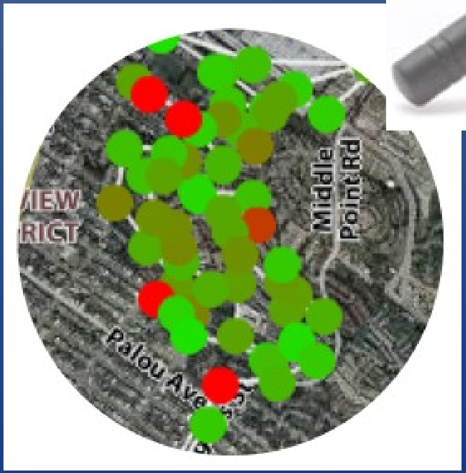
- What's freshest in the sensor network research community?

Sensor **Actuator** Networks

- Close the loop: the network responds to its own measurements
  - Examples
    - Distributed HVAC control
    - Factory control based on input

Social Sensing

- Citizen Science
- Use existing cell phones as sensors!



Notable Open Problems

- Time Synchronization
- Radio-based localization
- Effective deep-hop (3+) networks
- Make ever-small hardware (dust)

Learn More...

- **Berkeley (TinyOS, Mote Hardware)** - http://www.tinyos.net
- **ZebraNet** - http://www.princeton.edu/~mrm/zebranet.html
- **UCLA Nesl (SOS, Data Mule)** - http://nesl.ee.ucla.edu/
- **SensiCast** - http://www.sensicast.com
- **Sentilla** - http://www.sentilla.com
- **Sentilla Labs** - http://labs.sentilla.com
- **Streetline** - http://www.streetline.com
- **Synapsense** - http://www.synapsense.com

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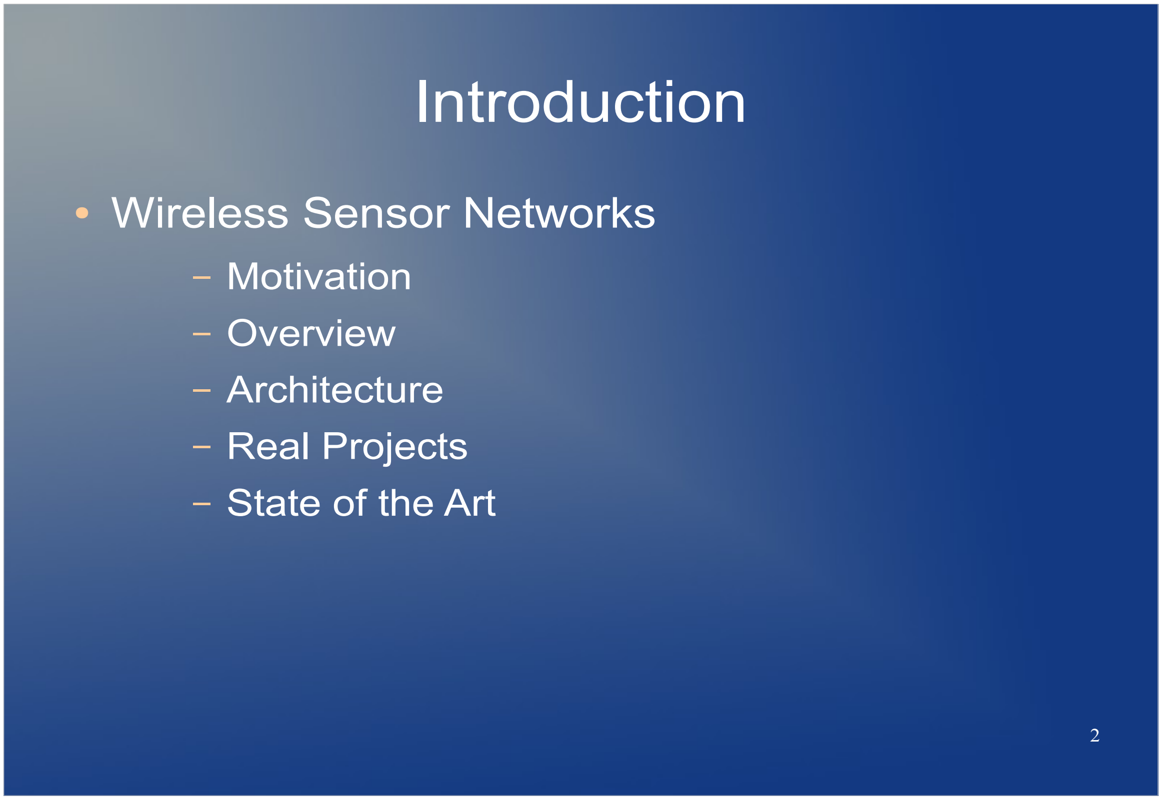
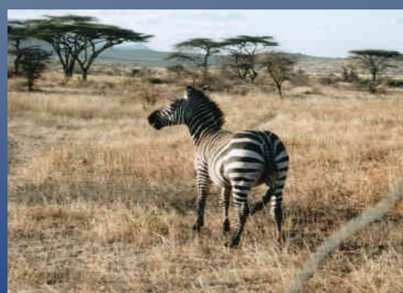


Introducing a special kind of wireless network. It has unique properties that give it it's own special class in the research and industry communities.

Motivation

- Let's look at two problems with very different environments



http://radlab.cs.berkeley.edu/saso2009/stuff/800px-Mark

http://www.gotpetsonline.com/pictures-gallery/exotic-pic

Problem

- Monitoring wildlife
  - Record interactions and proximity
  - Desolate areas
  - Large population
  - Devices must be unobtrusive

GPS not as practical because of bulkiness/energy requirements, and cost.

http://www.afripartners-safaris.com/afripartners/pix/serengeti.jpg

Problem

- City Parking
  - Thousands of spots distributed throughout a city
  - How do you find one?
  - How do you find violators?
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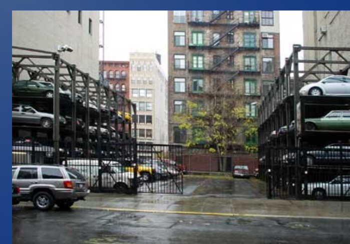

Adding instrumentation to existing urban infrastructure can be costly. Need to minimize it

http://www.midcityparking.com/image/2216778.jpeg

http://www.urban75.org/photos/newyork/images/ny253.j

What are the Requirements?

- Unobtrusive nodes
- Self-managing topologies
- Scalability to large numbers
- Connectivity with existing systems
- Programmability of data collection

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The challenges in the previous two problem statements are very similar, despite the very different environments

Enter Sensor Networks!

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  - A collection of **sensing nodes**
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  - Physically aware

Wireless sensor networks address these challenges

Key WSN Properties

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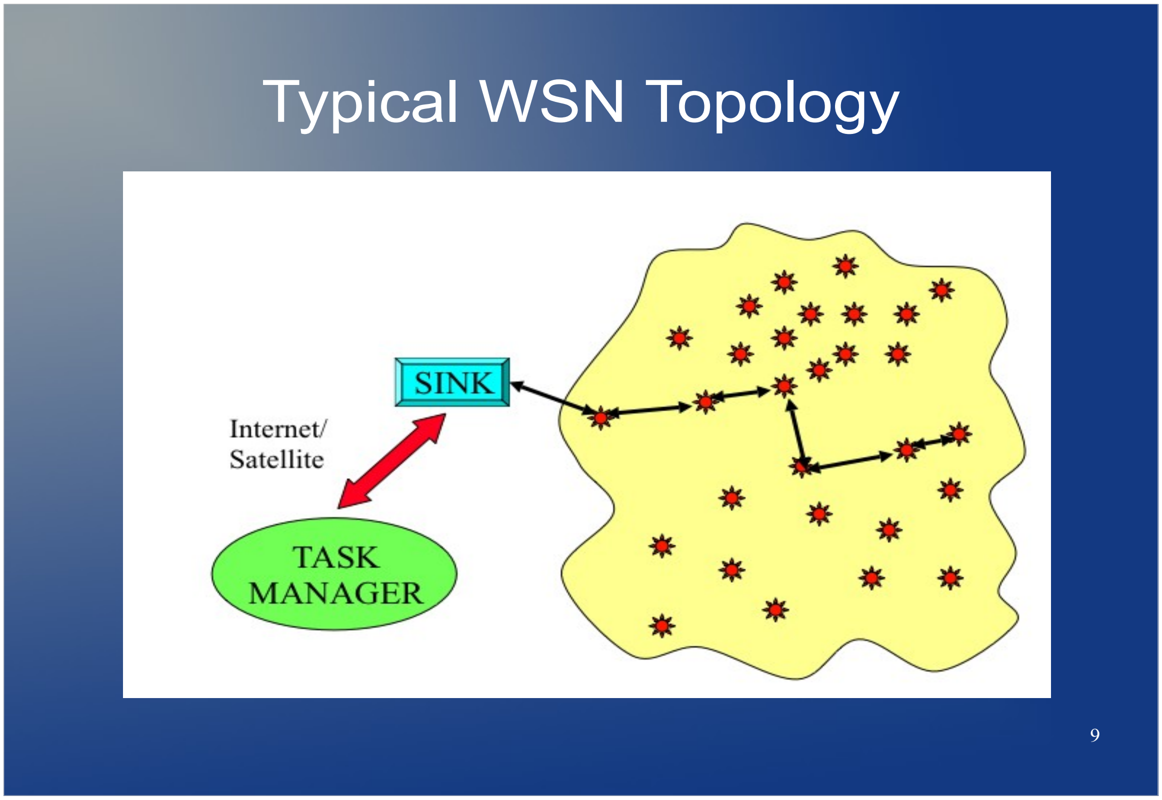
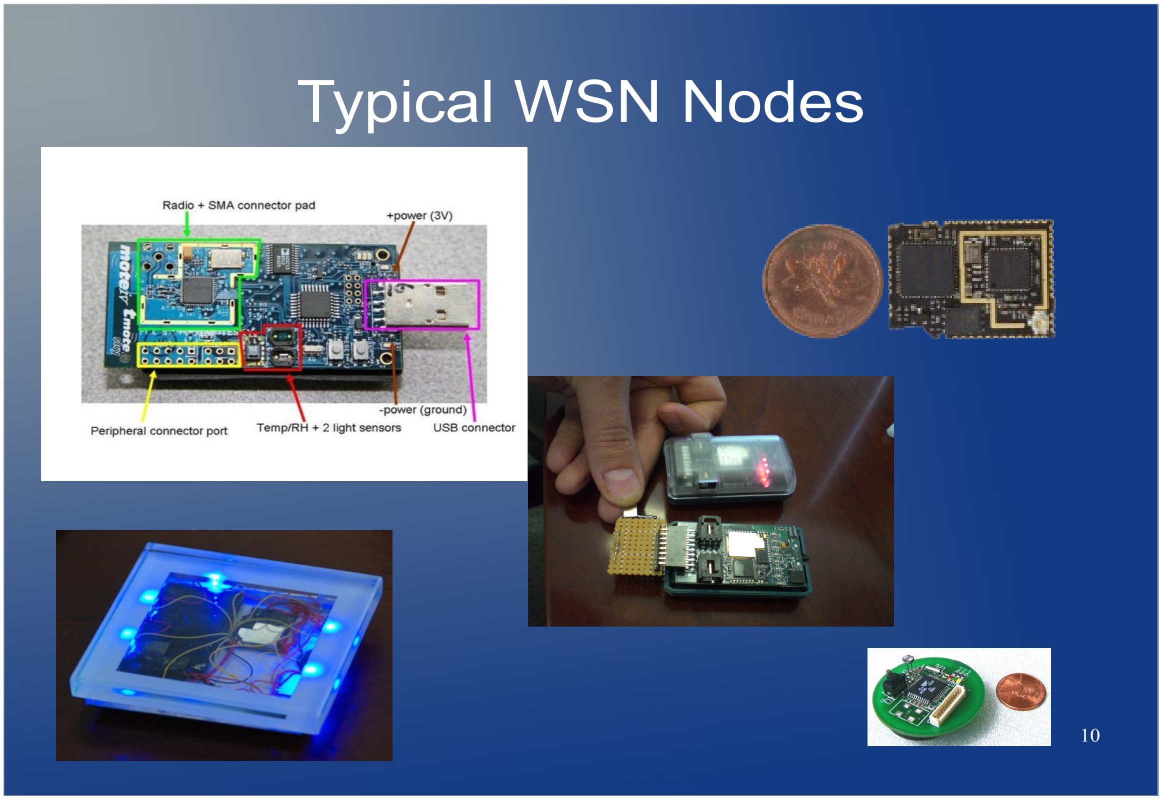


Mesh network, data aggregation points, eventually connectivity to the rest of the world

Conenctivity could be constant (internet pipe) or periodic (daily vehicular pickup, sneakernet, etc)



Very tiny computeres. Input: physical sensors, Compute: tiny microncontrollers, Output: wireless messages

For the round mote...I've seen "Smart Dust Mote" and "Berkeley Mote" -- I guess it's one of the old revisions
http://www.coe.berkeley.edu/labnotes/0701brainybuildings.html

Operating Systems

- Hardware access libraries
  - Sensors
  - Radio
  - Flash
- Very simple task scheduling
- TinyOS
  - Event driven
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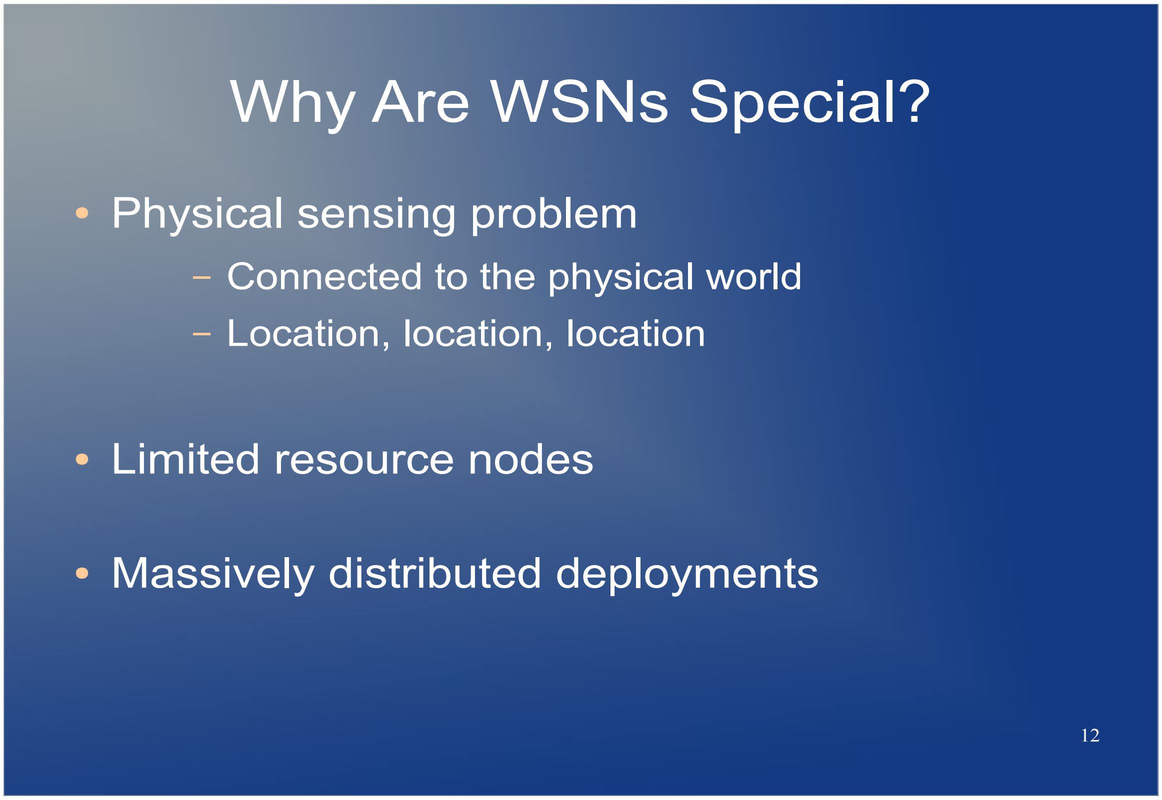


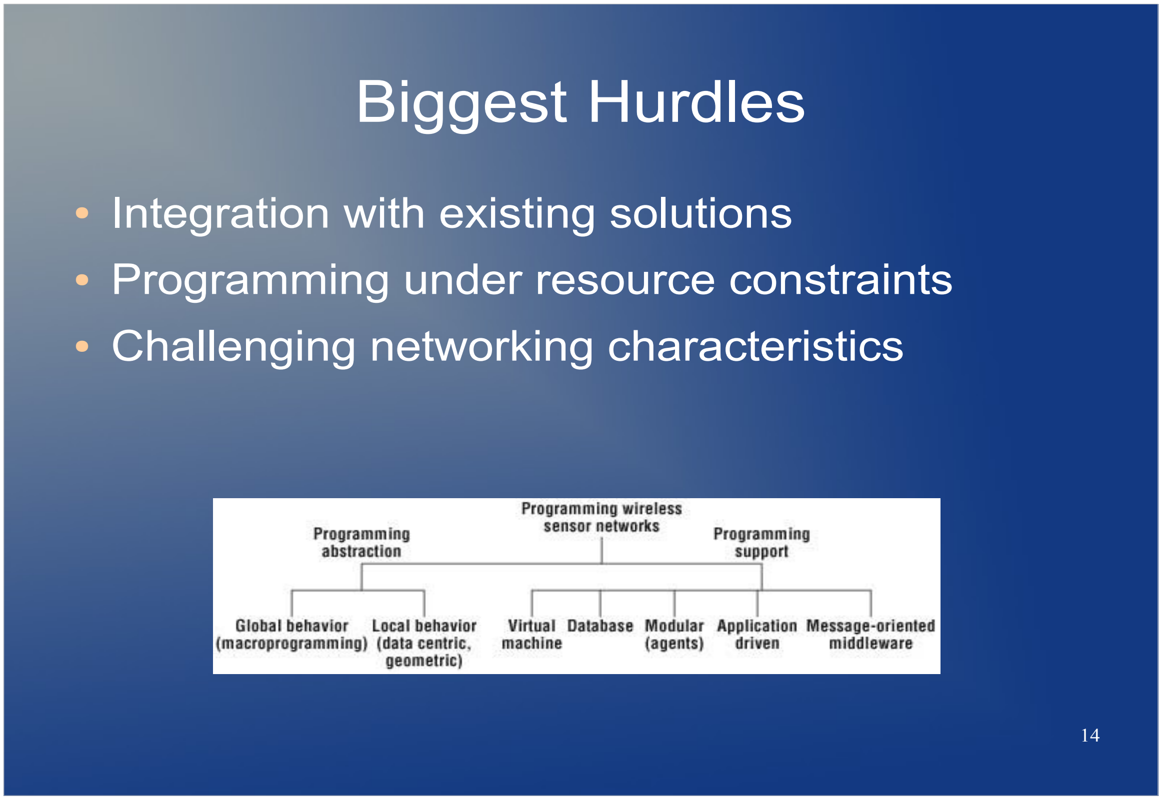
Because the nodes are sensing things from the world around them, the exact location of the node is often important. This places the potential for additional constraints when designing network nodes and topologies.

Biggest Hurdles

- Energy, energy, energy!
  - Hardware design of nodes is a huge problem
  - Wireless dominates
    - Particularly RECEIVING!

Energy gets its own slide

http://robfatland.net/seamonster/images/thumb/3/35/Field_mote_internal_assembly.png/500px-Field_mote_internal_assembly.png



To make use of the data, the measurements from WSN must be converted and stored in a way that makes sense for the end application, which is often a non-trivial solution.

The low-memory and low-power CPU mean that standard programming practices of this time don't apply anymore, in a practical sense. Much care much be taken, and often hacks or hardware tricks must be used.

The low-power network results in a large loss rate. Because of energy constraints, “always-on” listening is not always possible, adding additional challenges.

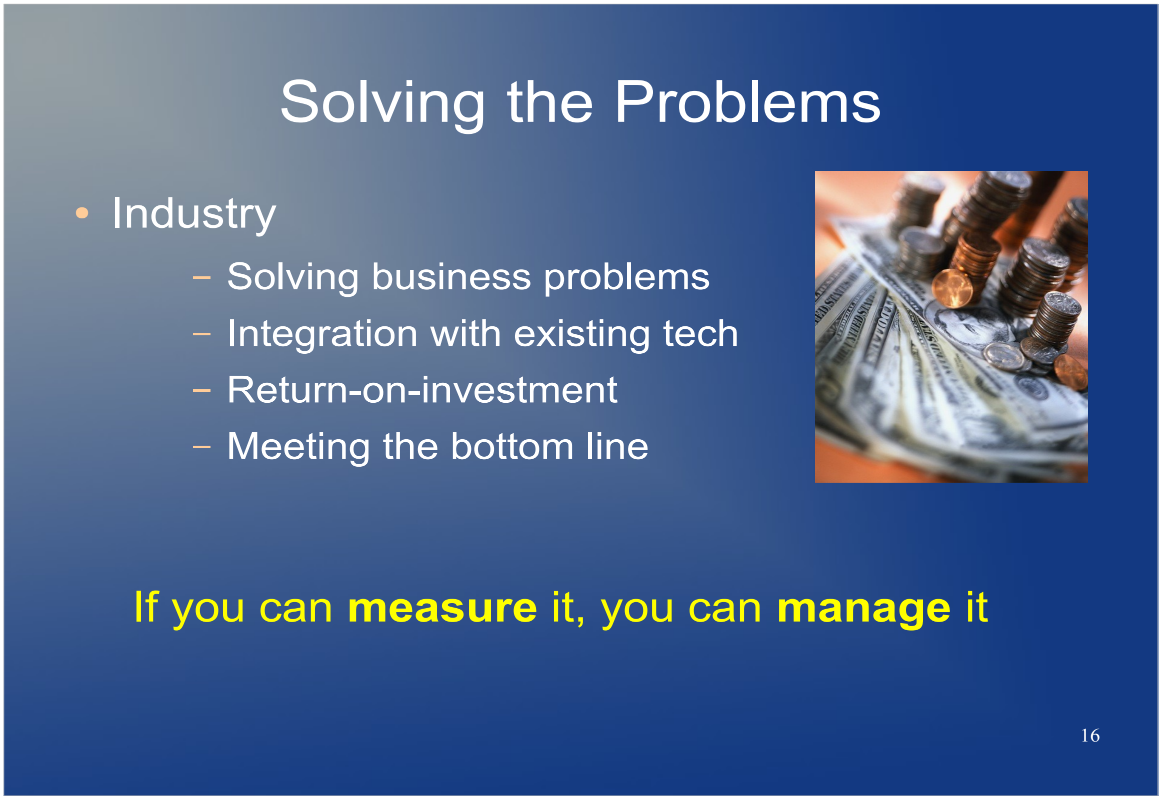
Solving the Problems

- Academia
  - Fun, challenging theoretical problems
  - Deployments that show neat data
  - Science experiments

If you can **measure** it, you can **analyze** it

How are the hurdles mentioned previously address? Well, academia focuses on one set of problems....

http://plus.maths.org/latestnews/may-aug05/millionaire/measure.jpg

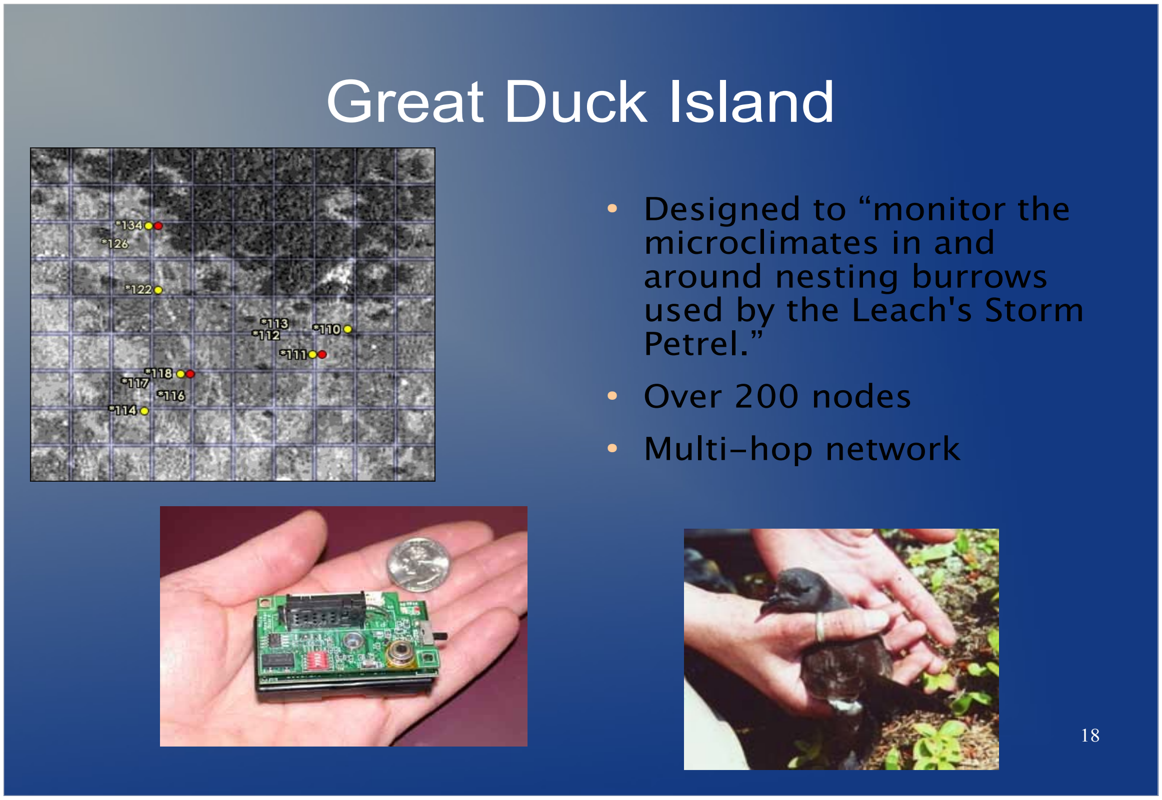


But industry and business focus on another

http://theseawards.com/media/1/Image/Money_Coins(1).jpg

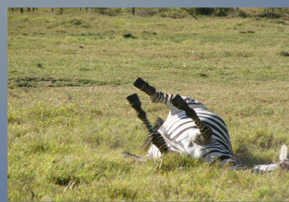
Some examples of academia research

Use the measure to understand slide

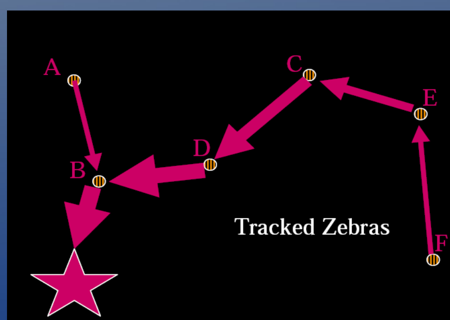


Monitor the environmental conditions of some birds

ZebraNet



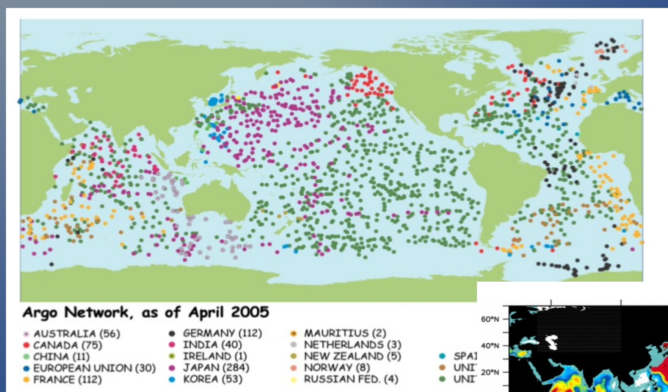
- Track wildlife in-situ
- Monitor movement, feeding, interaction patterns

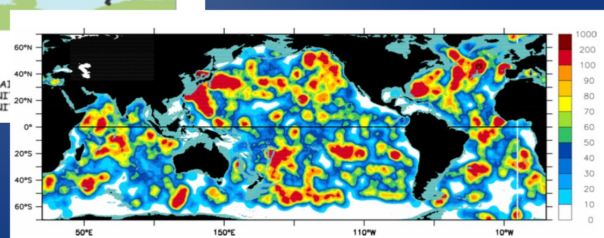


Track wildlife, monitor interactions

ARGO

- Measure Global Seawater Salinity





Very large scale salinity measurement

ARGO

- How could this be converted into a wireless sensor network?

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But, it's not a wireless sensor network! What if it was? How would things change?

(Discussion with class)

Survey: Industrial Projects

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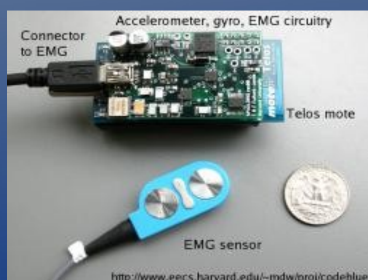
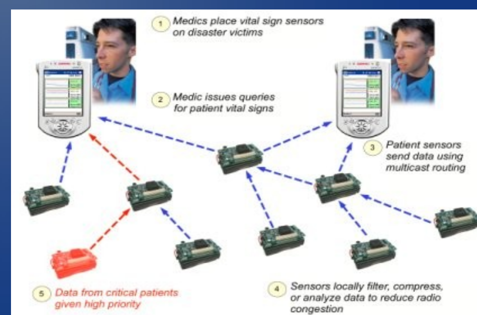
Business – data saves us money.... but not always as interesting problems

Codeblue

- Pre-Hospital Monitoring (triage)
- In-Hospital Monitoring
- Disaster Response
- Rehabilitation Assistance

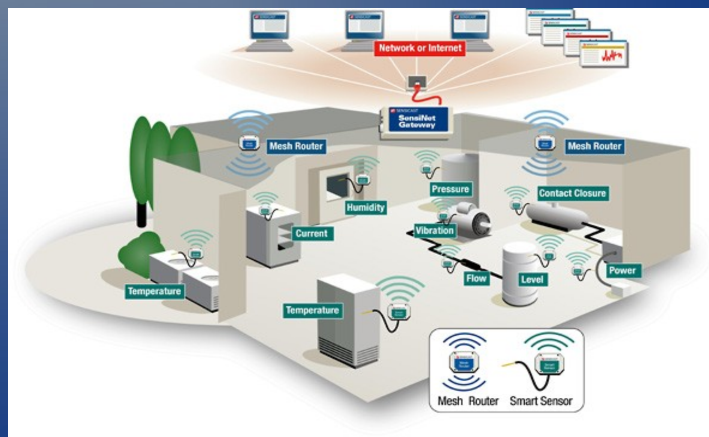




Health monitoring (WSN ER triage), saves resources in high-pressure health environments

SensiNet

- Industrial Process Monitoring
- Detect ineffeciencies to lower costs



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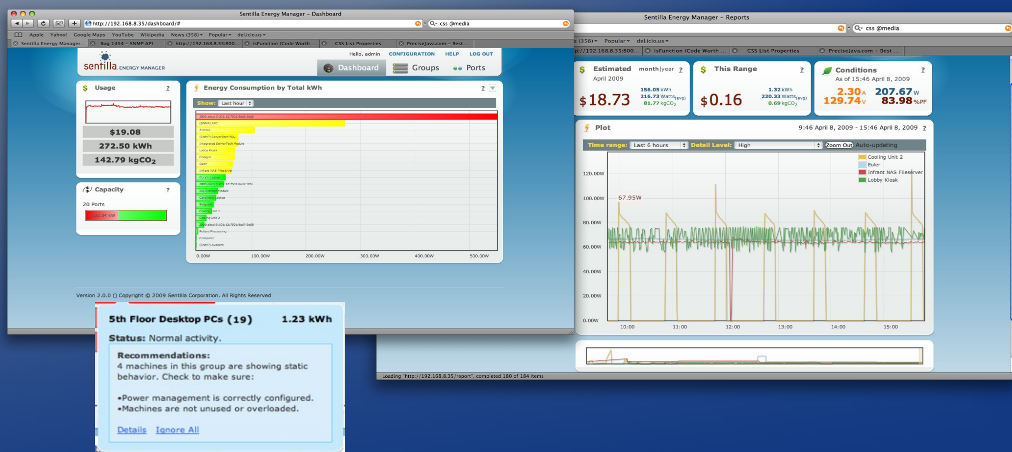
Eliminate downtime in a Steel Plant

Sentilla

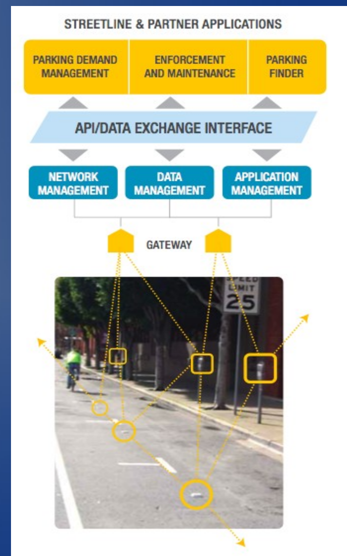
- Monitor energy usage in datacenters
- Detect opportunities for decreased consumption



Identify energy-saving opportunities in data centers

Streetline

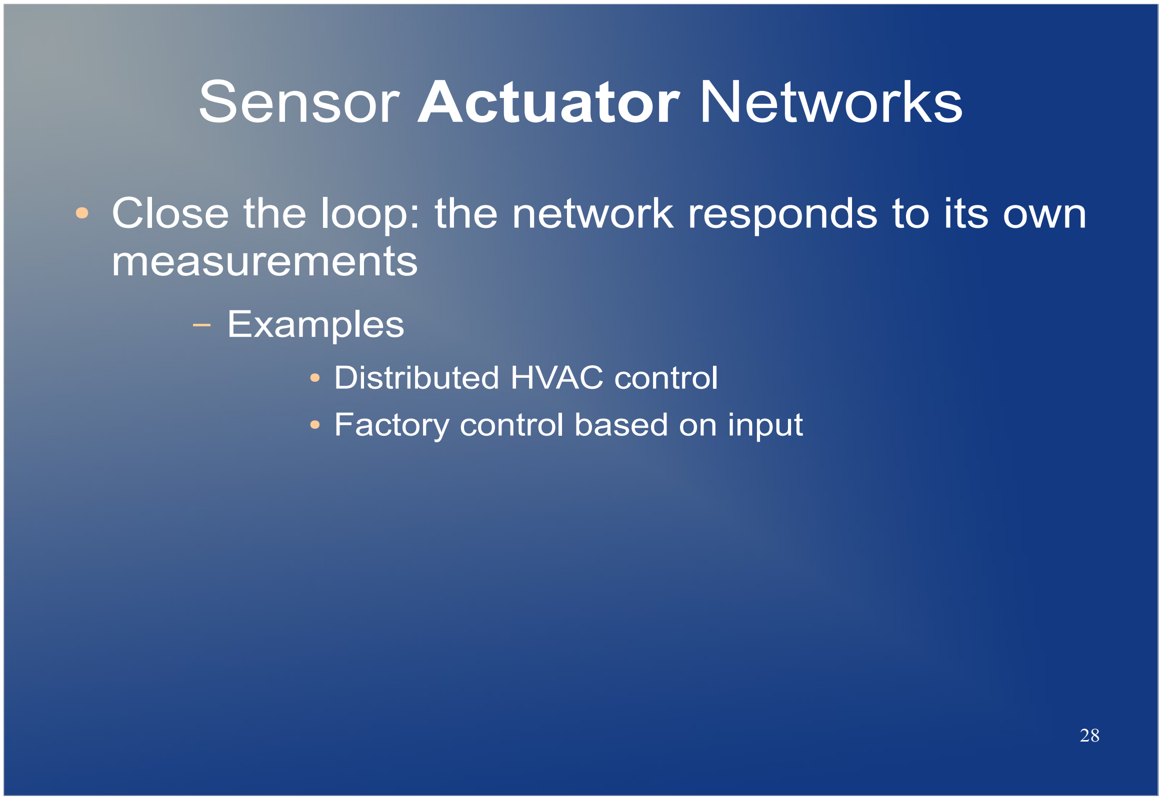
- Parking Management
- Traffic Monitoring



Parking monitoring

State of the Art

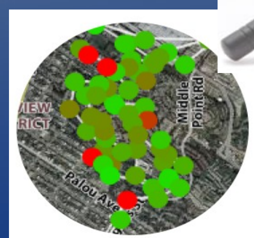
- What's freshest in the sensor network research community?



So far, we discuss data collection to learn or save money. But it could be taken a step further, with closed-loop sensor-actuator networks

Social Sensing

- Citizen Science
- Use existing cell phones as sensors!



Already lots of small computing devices out there. Take advantage of that... less control, but opportunitiy for more data collection in more places.

Notable Open Problems

- Time Synchronization
- Radio-based localization
- Effective deep-hop (3+) networks
- Make ever-small hardware (dust)

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There are tons of problems to solve. Here are the ones that pose the biggest challenge, and have the least satisfying solution to date.

Learn More...

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- **ZebraNet** - http://www.princeton.edu/~mrm/zebranet.html
- **UCLA Nesl (SOS, Data Mule)** - http://nesl.ee.ucla.edu/
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