



# **SENSING TECHNOLOGIES FOR DATA COLLECTION AND MONITORING**

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**DIL '14 – STATE OF THE SCIENCE**

# Data is empowering



[UFL BuildGreen]

## Regions of Strong Coupling Between Soil Moisture and Precipitation

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Previous estimates of land-atmosphere interaction (the impact of soil moisture on precipitation) have been limited by a lack of observational data and by the model dependence of computational estimates. To counter the second limitation, a dozen climate-modeling groups have recently performed the same highly controlled numerical experiment as part of a coordinated comparison project. This allows a multimodel estimation of the regions on Earth where precipitation is affected by soil moisture anomalies during Northern Hemisphere summer. Potential benefits of this estimation may include improved seasonal rainfall forecasts.

Atmospheric chaos severely limits the predictability of precipitation on seasonal time scales. Weather forecasts, which rely heavily on atmospheric initialization, rarely demonstrate skill beyond about a week. Hope for accurate seasonal forecasts lies with simulating the atmospheric response

to slowly varying states of the ocean and land surface—components of the Earth system that can be predicted weeks to months in advance. A systematic response of the atmosphere to these boundary components would contribute skill to seasonal prediction.

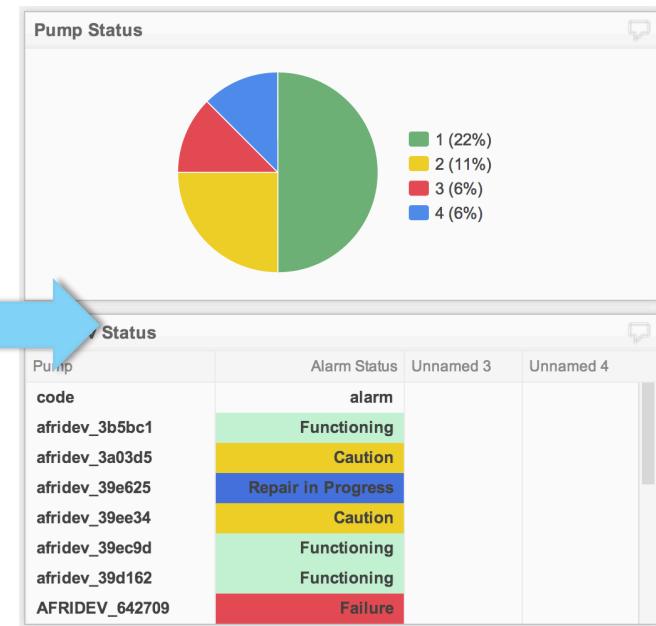
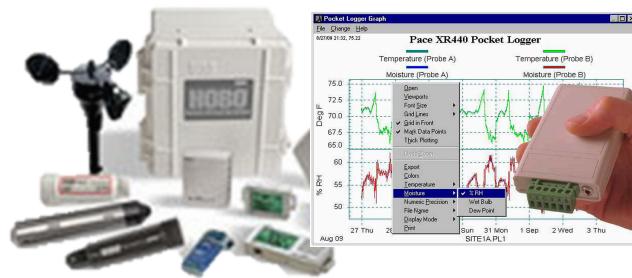
[GLACE Team Rainfall Estimation]

# Where does data come from?

## Sensors

Used to get data from the physical world to the digital world

## Automated, continuous data collectors



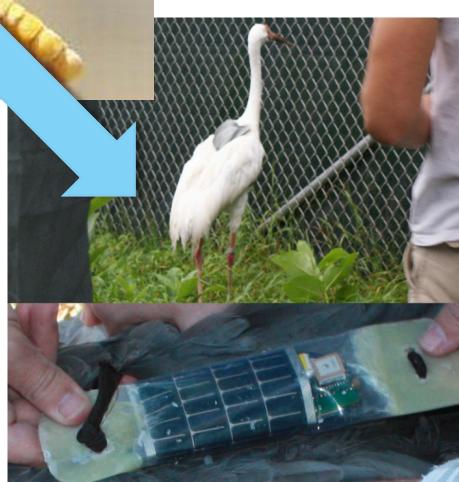
[SweetSense]

# The most important question in planning your deployment, part 1

How often do I need to get data from my sensors?



[Global Seismographic Network]



[Bennet: Crane Charades]



[Seismic Surveys]

Real-time

Periodic

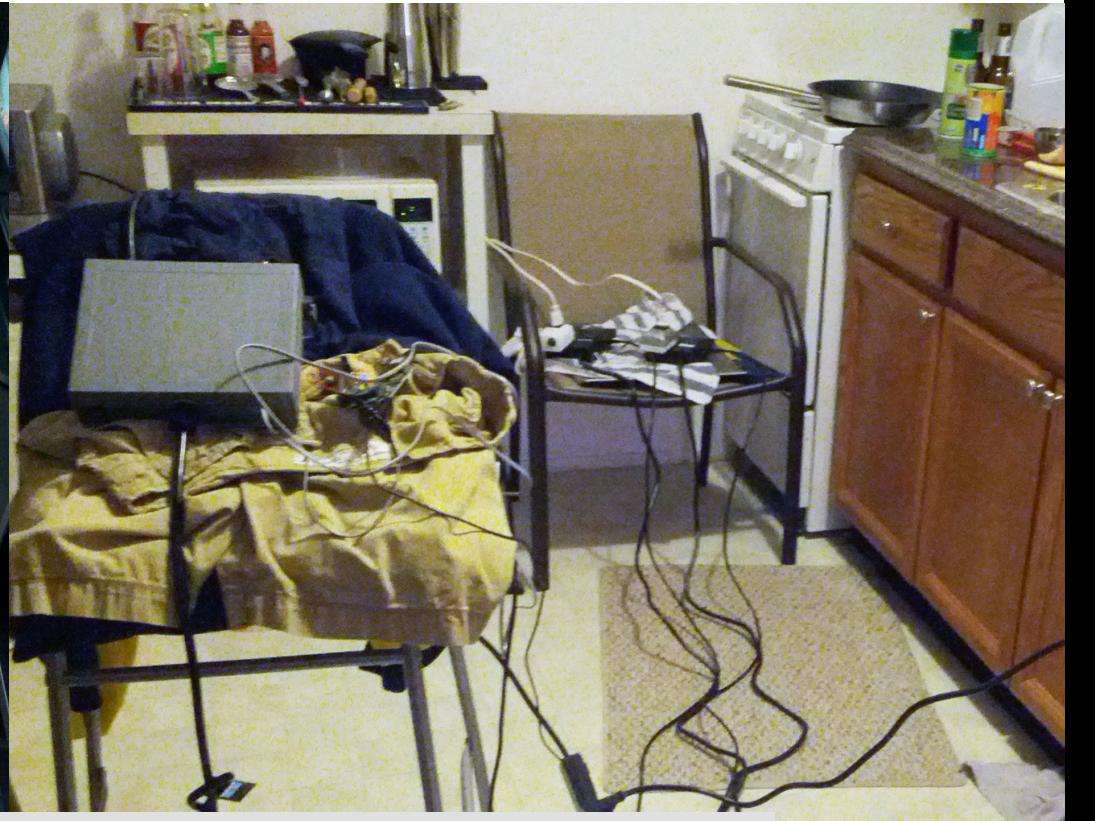
Single Dump

**How am I going to get  
data off of my sensors?**

# All forms of communication are not created equal



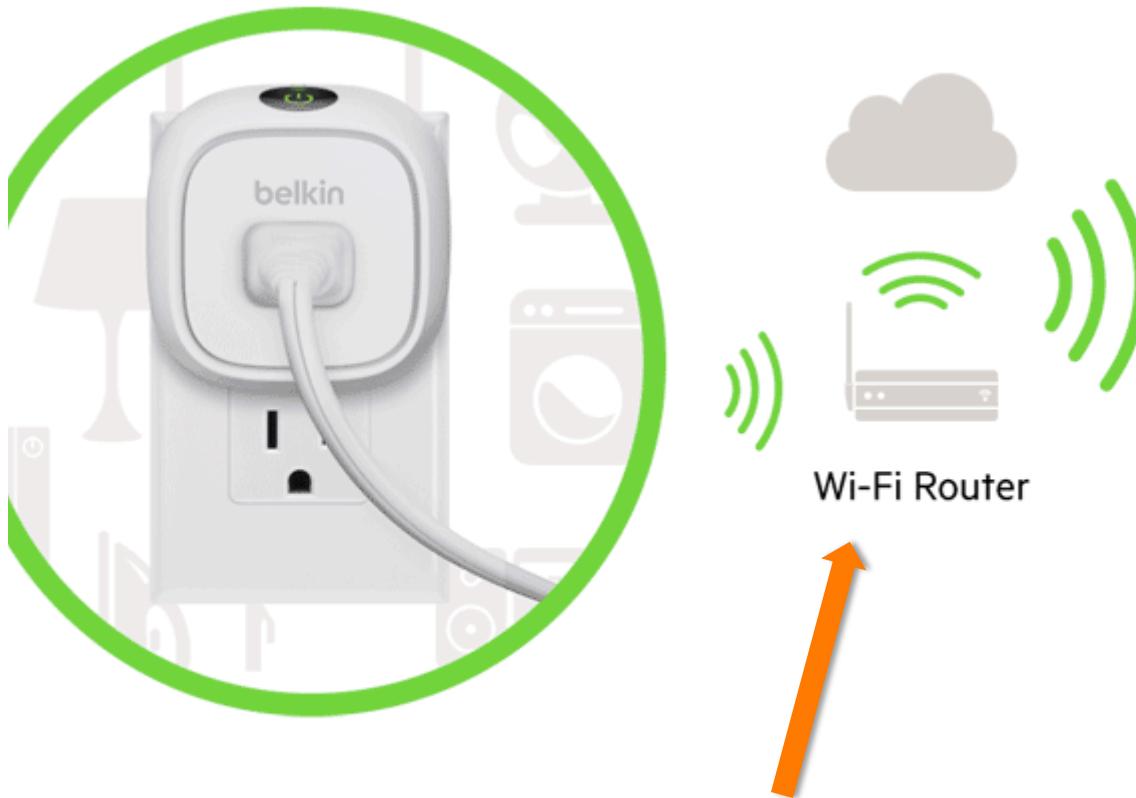
# Instrumenting a home with WattsUp.net



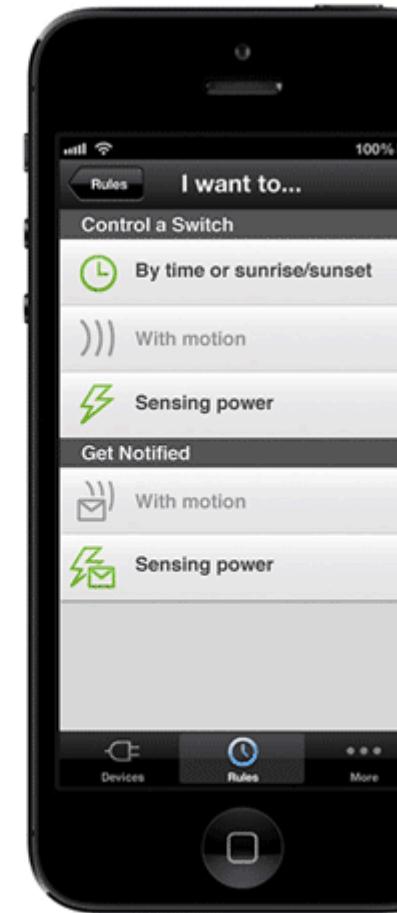
Infrastructure



# **Going wireless does not eliminate infrastructure costs, it only shifts it**

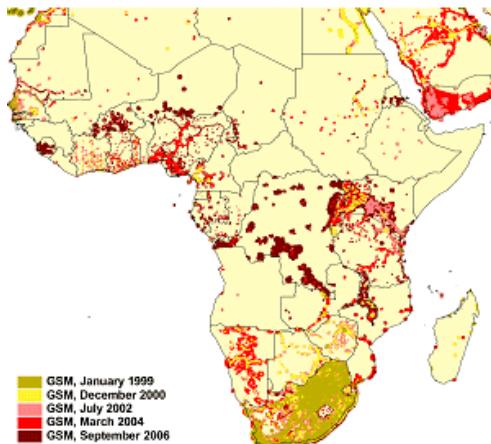


## **Hidden Infrastructure**

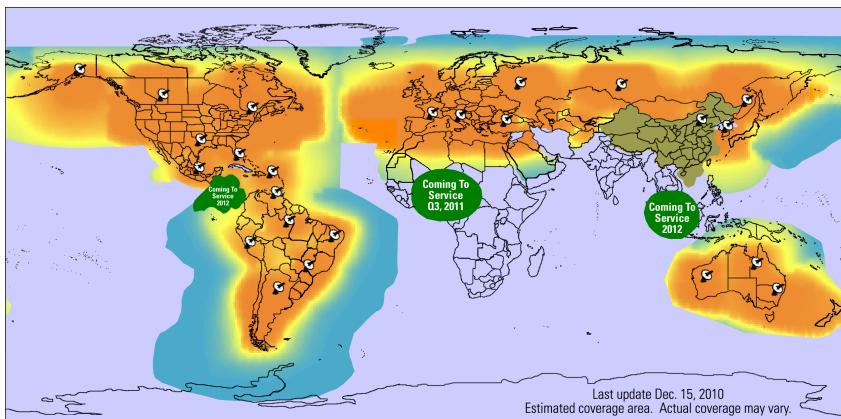
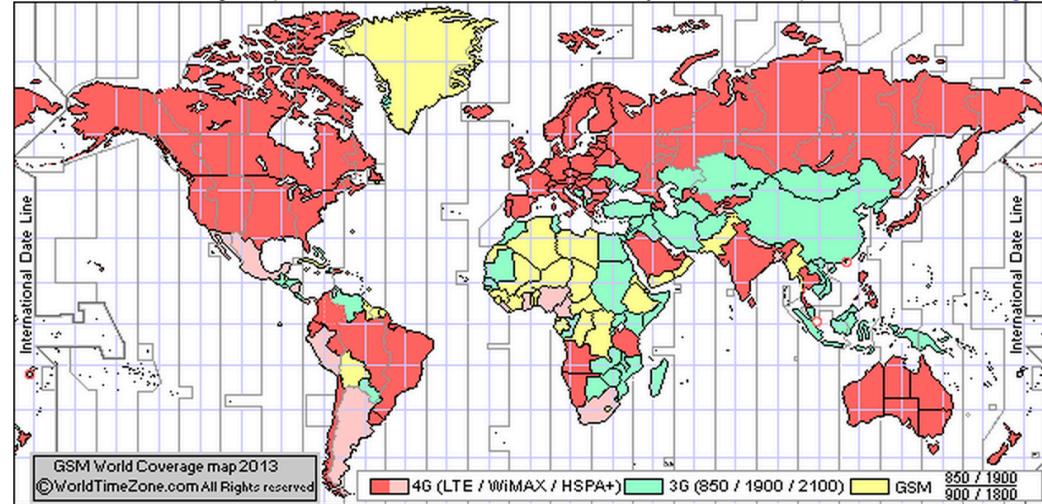


# There is no truly ubiquitous communications infrastructure

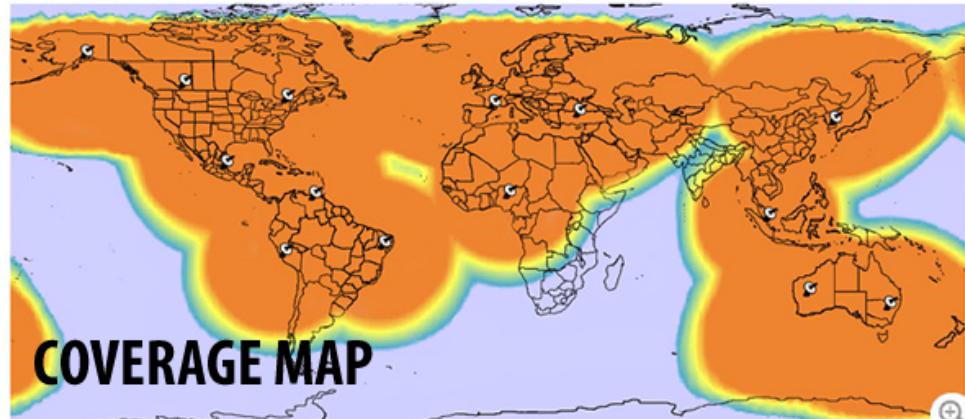
Figure 1 GSM cell phone expansion in Sub-Saharan Africa, 1999 – 2006



4G LTE World Coverage Map - LTE, WiMAX, HSPA+, 3G, GSM Country List. [View Map of GSM World Coverage](#)



[satphonestore.com coverage, 2010]



[satphonestore.com coverage, 2011]

# The next question:

## How am I going to power my sensor?

**Informed by the previous questions**

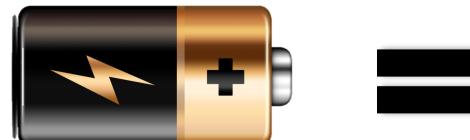
Batch Offloading is easy:

Battery size proportional to data size

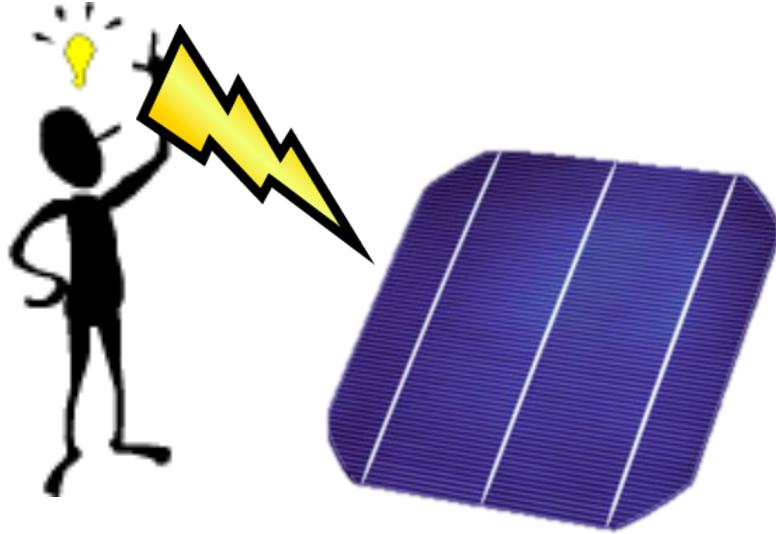
Wired networks:

Relative cost of adding power wires is low (usually)

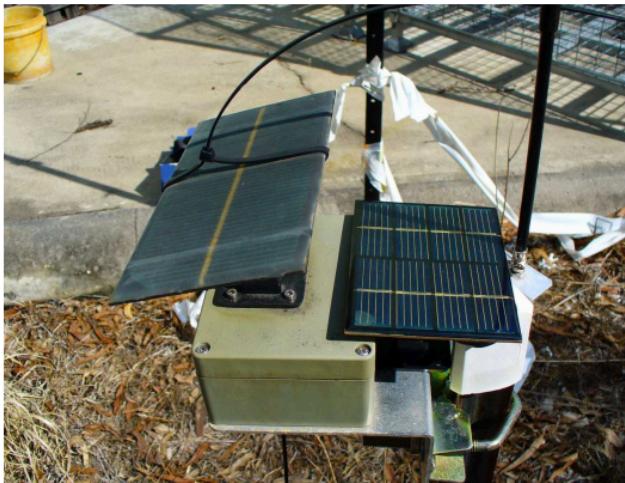
Wireless...



# Idea: Do we need a battery?



[UMass RiverNet]



[CSIRO Fleck1]

**Up until now, we have discussed  
“Traditional Sensing”**

**To sense temperature, use a temperature sensor**

# **Systems goals do not necessarily map directly to sensing goals**

**“I need a sensor that measures water flow”**

- + Mechanically challenging

**“It needs to be wireless and last for several months”**

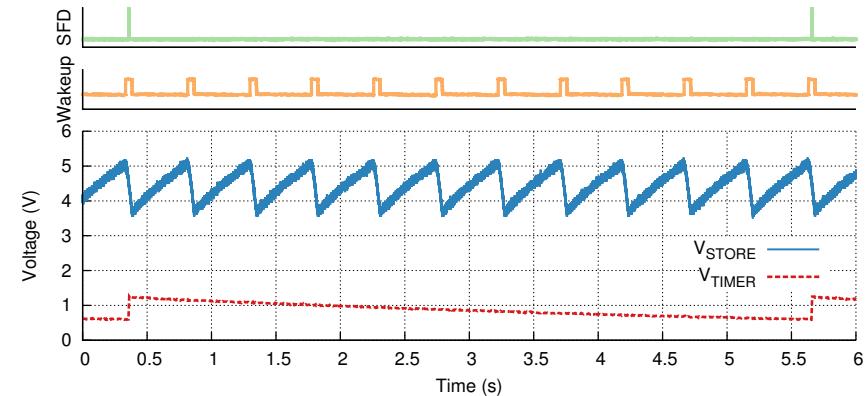
**“I want to measure if people wash their hands after they use the toilet”**

**You actually want a temperature sensor**

# The Monjolo Principle

Combining non-traditional sensing and energy harvesting

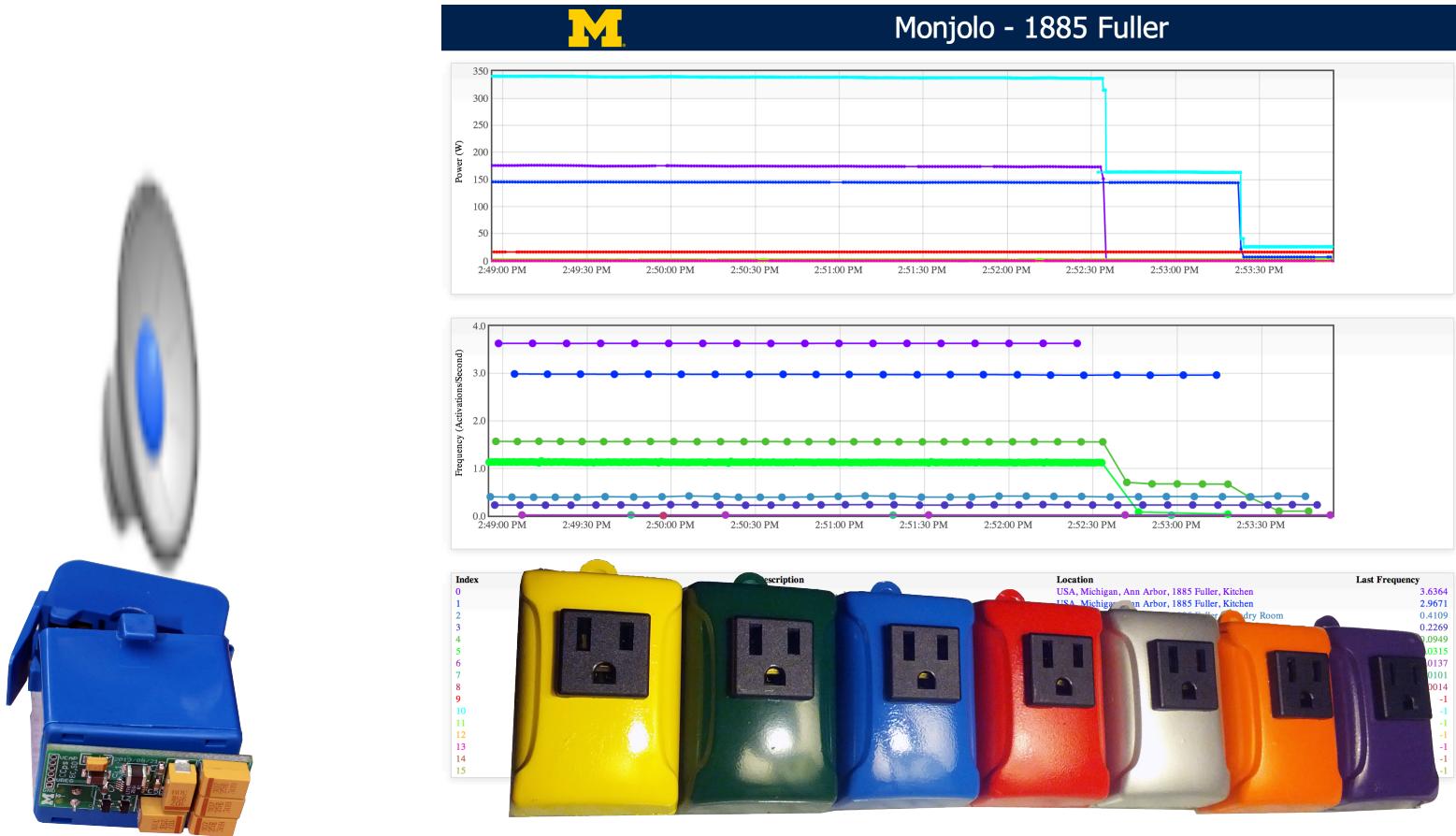
Harvest side-channels of energy – wakeup frequency is the sensor



[Monjolo, Sensys '13]

# Monjolo in action

<http://inductor.eecs.umich.edu/pathouse.html>



# I have neglected the most deployed sensor in the world...

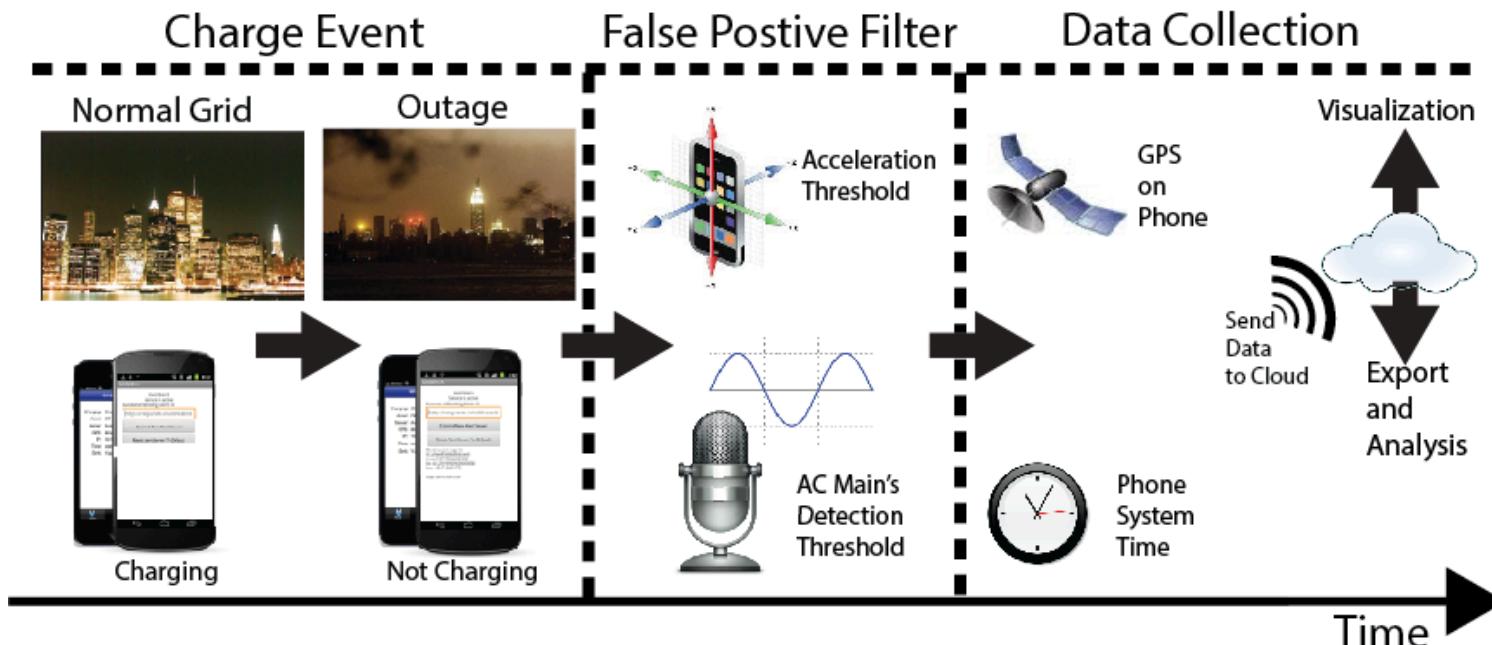
The Smartphone!



# GridWatch: Crowdsourcing power grid health monitoring

**Insight:** You pick up your phone to unplug it

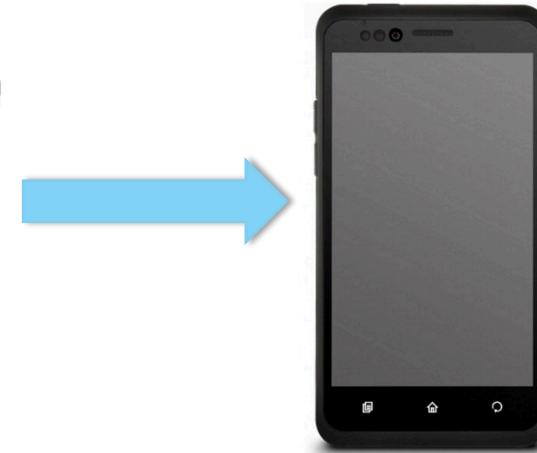
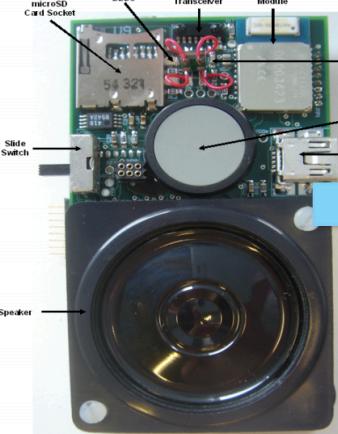
- + Power loss without motion is likely a power outage



# Smartphones have a diverse array of powerful sensors

Accelerometer, Gyroscope, Magnetometer, GPS, camera, ...

And communication (cellular, WiFi, Bluetooth, NFC) is built in

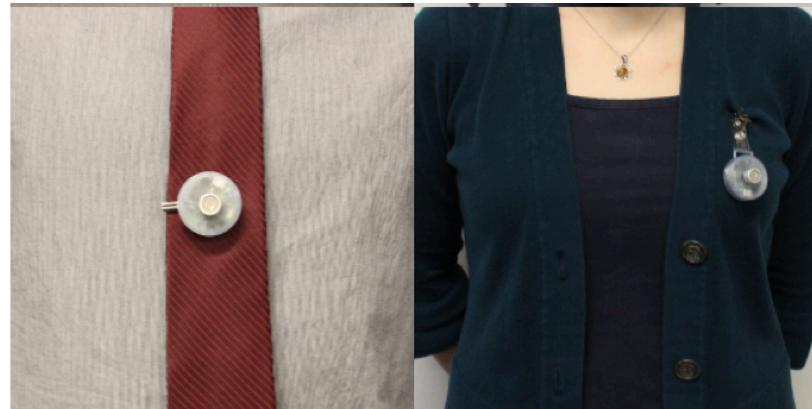


Pentland '06

Pentland '07

Pentland '09

# Why do people still build hardware if smartphones exist?



## Cost

Don't need a \$100 smartphone to do the job of a \$1 compass

## Performance

Does this matter? Maybe.

## Availability of sensors

...

[Opo: Pre-publication]

# Augmenting smartphones to add “missing” sensors



Geiger Counter



EKG Monitor



Thermometer



CC Terminal



CO Sensor



Soil Moisture

[slide courtesy Prabal Dutta]

# **Takeaways**

**If you can think something to measure, it can be measured**

Though measuring it directly may not always be the best approach

**Constraints on data-collection define the rest of your system**

Or at the least are a very good place to start

**Smartphones are useful, but not a panacea**

And can be costly (though re- and multi-purposeable)

# **Ask not what you can do for DIL, but what DIL can do for you**

**Problems, challenges, we need them!**

**What is interesting to collect?**

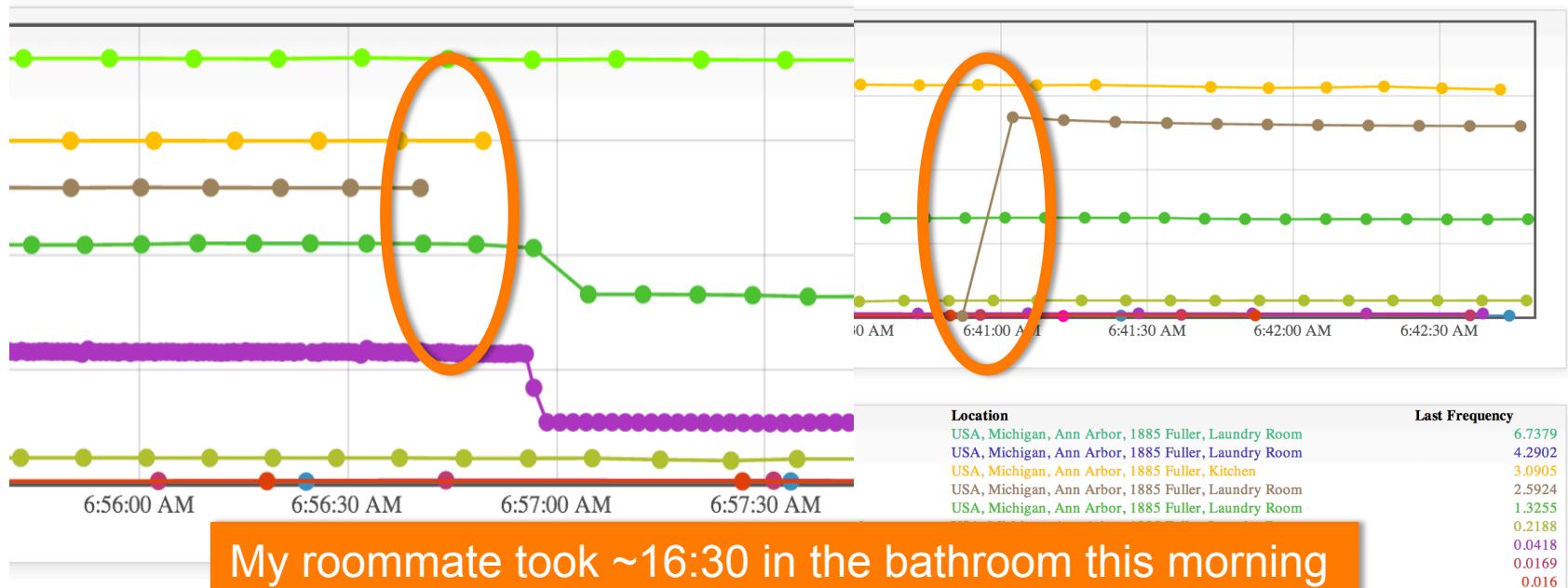
**What constraints aren't we seeing?**

Especially those that are developing world related

# Cultural help: We like data too much for our own good

We can see devices turn on / off

Lose sight of the fact that humans are turning them on and off



## Privacy implications

What should a system like this look like?

# I have lots of cool hardware with me today – come find me!



**lab11.eecs.umich.edu**



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## Noah Klugman

- GridWatch
- Mobile Health



## Meghan Clark

- Smart Buildings
- Disaggregation



## Sam DeBruin

- Energy Harvesting
- AC Power Meters

## Ben Kempke

- RF ranging
- Radio design



## Pat Pannuto

- mm<sup>3</sup> systems
- VLC
- {e,si}mulation

## Brad Campbell

- Energy Harvesting
- 15.4, TinyOS



## Branden Ghena

- Gaze Tracking



## YeSheng Kuo

- μSDR
- VLC, Floodcasting