Distributed Pervasive Systems

CS677 Guest Lecture

Tian Guo

Outline

- Distributed Pervasive Systems
  - Popular Application domains
  - Sensor nodes and networks

- Energy in Distributed Systems (Green Computing)
  - Data Center Energy Consumption
  - Smart Building Case Study

Pervasive Computing

- Computing becomes pervasive or ubiquitous

- Rise of "devices"
- Computing everywhere
  - smart cities, smart homes, smart highways, smart classroom, ...

Rise of Pervasive Computing

- Internet of things
  - ability to network devices and have them communicate
- Sensor networks
  - Large networks of sensors
- Driven by miniaturization of computing
  - Tiny sensors with computing and communication capability

Example Applications

- Smart home

Computer Science

Personal Health Monitoring

- Sensors to monitor fitness, diabetes, blood pressure, detect falls

Google tests prototype of diabetes-tracking 'smart' contact lens

Typical Smart Apps

- Personal device to mobile phone to the cloud
  - Upload data to cloud via a mobile device (or directly)
  - Low-power communication to phone
  - Cloud provides analytics and provides feedback to phone

- Environmental sensors to internet to the cloud
  - Internet-enabled sensors
  - direct upload to servers / cloud
  - Cloud provides analytics and provides dashboard

Sensor Platform

- Smart devices are a sensor node

- Resource-constrained distributed system

- Typical Sensor platform
  - Low-power radios for communication
    - 10-200kbit/sec
  - Small CPUs
    - E.g. 8bit, 4k RAM.
  - Flash storage
  - Sensors
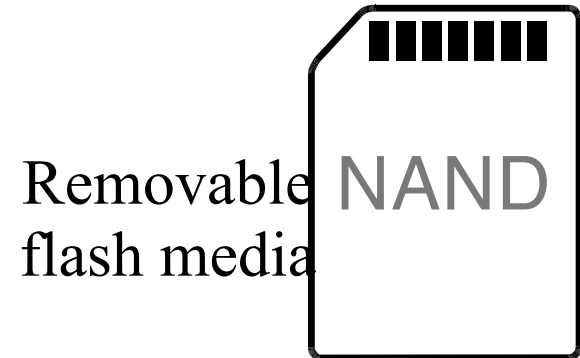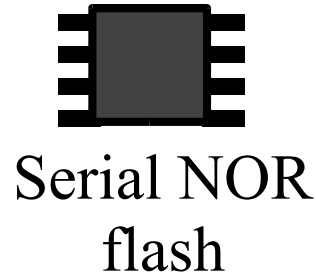 - Battery driven or self-powered

Low Power Radios

- ISM band – 430, 900, or 2400 MHz
- Varying modulation and protocol:
  - Custom (FSK?) – Mica2, 20 kbit/s
  - Bluetooth ~ 1 Mbit/sec
  - Zigbee (802.15.4) - ~200kbit/sec
  - Z-wave ~ 40kbit/sec
- Short range
  - Typically <100 meters
- Low power. E.g. Chipcon CC2420:
  - 9-17 mA transmit (depending on output level)
  - 19 mA receive
- Listening can take more energy than transmitting

Small CPUs

- Example: Atmel AVR
  - 8 bit
  - 4 KB RAM
  - 128 KB code flash
  - ~2 MIPS @ 8MHz
  - ~8 mA
- Example: TI MSP430
  - 16 bit (sort of)
  - 10 KB RAM
  - 48 KB code flash
  - 2 mA

MSP430x20x1 BLOCK DIAGRAM

Higher-powered processors:
ARM7 (Yale XYZ platform)
32 bit, 50 MHz, >>1MB RAM
ARM9 (StarGate, others)
32 bit, 400 MHz, >>16MB RAM

Flash Storage

Serial NOR
flash

NAND
flash

Removable
flash media

NAND

- Raw flash

"Cooked" flash

- Small (serial NOR), very low power (NAND)

- Page-at-a-time write

Disk-like interface
512B re-writable blocks
Very convenient
Higher power consumption

- No overwrite without erasing

- Divided into pages and erase blocks

- Typical values: 512B pages,
  32 pages in erase block

- Garbage collection needed to gather free pages for erasing

Battery Power

- Example: Mica2 "mote"
- Total battery capacity: 2500mAH (2 AA cells)
- System consumption: 25 mA (CPU and radio on)
- Lifetime: 100 hours (4 days)
-
- Alternatives:
  - Bigger batteries
  - Duty cycling
  - Solar/wind/… ("energy harvesting")

Self-harvesting Sensors

- Harvest energy from environment to power themselves
  - tiny solar panels, use vibration, airflow, or wireless energy
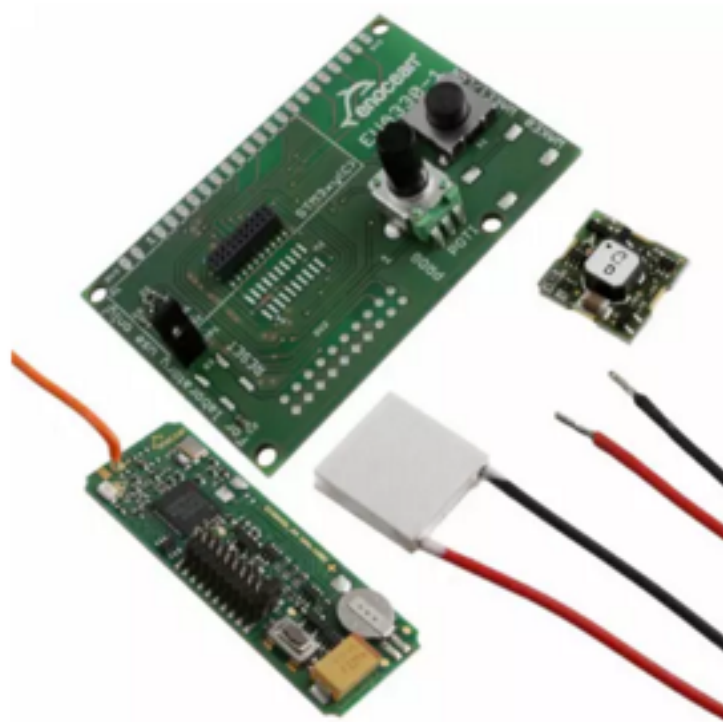
Sensors

- Temperature
- Humidity
- Magnetometer
- Vibration
- Acoustic
- Light
- Motion (e.g. passive IR)
- Imaging (cameras)
- Ultrasonic ranging
- GPS
- Lots of others…

Typical Design Issues

- Single node
  - Battery power or how to harvest energy to maximize lifetime

- Inside a network of sensors
  - Data aggregation
  - Duty cycling
  - Localization, Synchronization
  - Routing

- Once data is brought out of the network (server-side processing)
  - "Big data" analytics
  - Derive insights
  - Make recommendations, send alerts
  - Provide active control

Computer Science
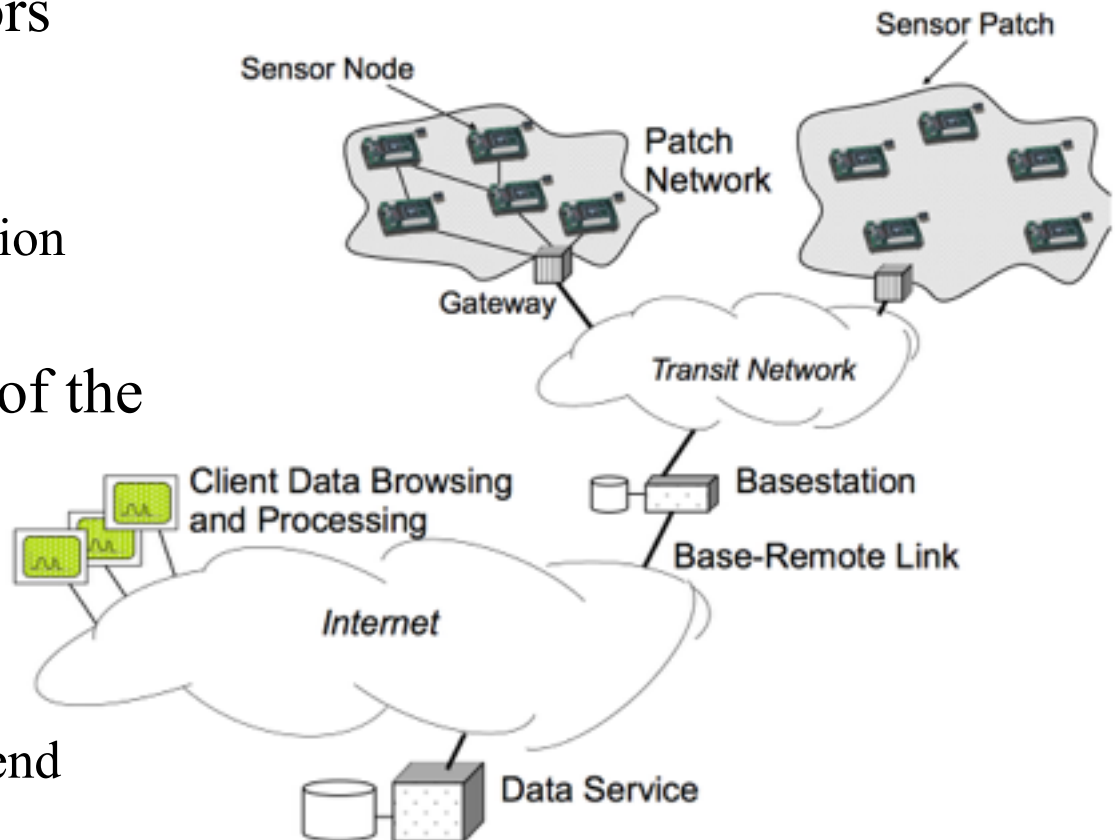
Green Computing

- Greening of computing
  - Sustainable IT
  - How to design energy-efficient hardware, software and systems?

- Computing for Greening
  - Use of IT to make physical infrastructure efficient?
    - Homes, offices, buildings, transportation

Some History

- Energy-efficient mobile devices a long standing problem
  - Motivation: better battery life, not green

- Recent growth of data centers
  - More energy-efficient server design
  - Motivation: lower electricity bills
    - Green systems, lower carbon footprint
- Apply "Greening" to other systems
  - IT for Greening

Computing and Power Consumption

- Energy to Compute
  - 20% power usage in office buildings
  - 50%-80% at a large college
  - 3% of our carbon footprint and growing
- Data centers are a large fraction of the IT carbon footprint
  - PCs, mobile devices also a significant part

Computer Science

What is a data center?

- Facility for housing a large number of servers and data storage
- Google data center (Dalles, OR)
  - 12 football fields in size
    - Compare to box stores!
  - 100 MW of power
    - Enough for a small city
  - ~ 100K servers

Each data center is
11.5 times
the size of a football field

Energy Bill of a Google Data center

- Assume 100,000 servers
- Monthly cost of 1 server
  - 500W server
  - Cost=(Watts X Hours / 1000) * cost per KWH
  - Always-on server monthly cost = $50
- Monthly bill for 100K servers = $5M
- What about cost of cooling?
  - Use PUE (power usage efficiency)
  - PUE =2 => cost doubles
  - Google PUE of 1.2 => 20% extra on 5M (~ $6M)

How to design green data centers?

- A green data center will
  - Reduce the cost of running servers
  - Cut cooling costs
  - Employ green best practices for infrastructure

Reducing server energy cost

- Buy / design energy-efficient servers
    - Better hardware, better power supplies
    - DC is more energy-efficient than AC

- Manage your servers better!
    - Intelligent power management
    - Turn off servers when not in use
    - Virtualization => can move apps around

Reducing cooling costs

- Better air conditioning
  - Thermal engineering / better airflow
  - Move work to cooler regions
- Newer cooling
  - Naturally cooled data centers
  - Underground bunkers
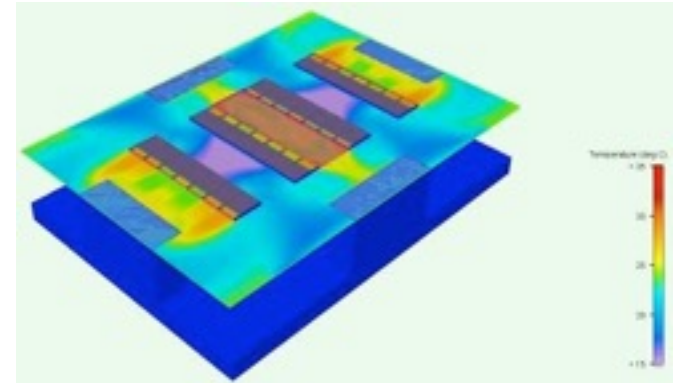
Invest in Iceland Agency

| HOME | ABOUT US | PUBLICATIONS | REPORTS | NEWS | LINKS | CONTACT US | REQUEST CALL-BACK |

Doing Business in Iceland
Investment Opportunities
→ Power Sources
→ Energy intensive
→ Data Centers in Iceland
Iceland within Reach
Locations
Request Call-back

Film in Iceland
invest in Skagafjörður

Path: News

25. June 2007
Iceland: Outstanding location for Data Centers
According to a benchmarking study, by Price Waterhouse Coopers in Belgium for Invest in Iceland Ag
Orkuvelta Reykjavíkur, Farice, Siminn, and Landsvirkjun, Iceland stands out as a location for Data Cer

Iceland can offer clean, renewable energy at a very competitive price and the study showed that
Iceland offers lower cost for Data Centers than USA, UK and even India. This makes Iceland a very
attractive location for Data Centers, and even more so if taken into account the fact that the need
for cooling is substantially less in Iceland, due to a cooler climate, and that the energy in Iceland is
renewable. Studies have shown that half of the energy cost of a Data Center is for cooling, making
Iceland an even more ideal location. Furthermore, Iceland provides only hydro-electric and/or geo-
thermal energy, which is renewable and therefore environmentally friendly, does not contribute to
global warming, and requires no carbon credits.

Desktop Power management

- Large companies => 50K desktops or more
  - Always on: no one switches them off at night
  - Night IT tasks: backups, patches etc
- Better desktop power management
  - Automatic sleep policies
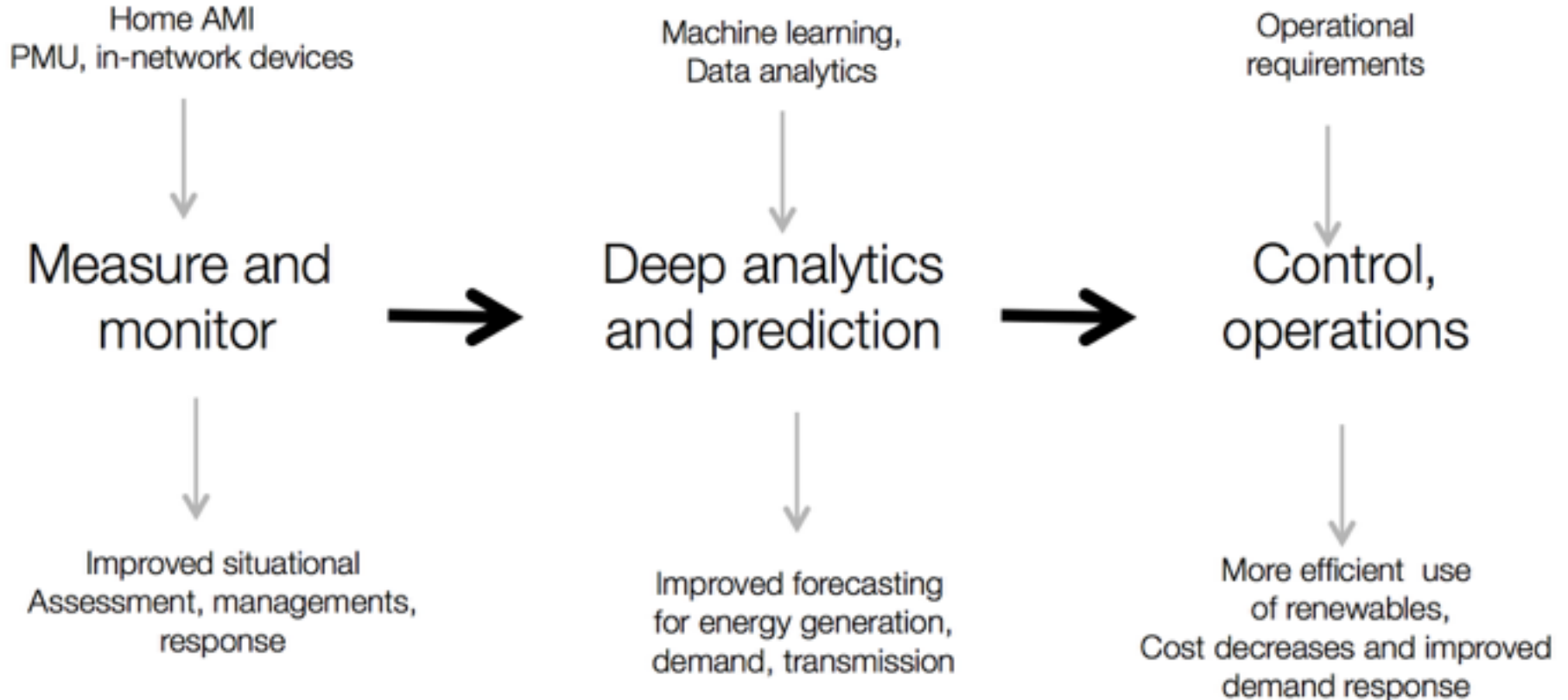 - Automatic / easy wakeups [see Usenix 2010]

IT for Greening

- Case Study: Smart Buildings
- Buildings as an example of a distributed system
  - Distributed pervasive system
  - Sensors monitor energy, occupancy, temperature etc
  - Analyze data
  - Exercise control
    - Switch of lights or turn down heat in unoccupied zones
  - Use renewables to reduce carbon footprint

- How can we use IT to make building green?
  - Use sensors, smart software, smart appliances, smart meters .....

Approach

Home AMI
PMU, in-network devices
↓
Measure and monitor
↓
Improved situational Assessment, managements, response

→

Machine learning, Data analytics
↓
Deep analytics and prediction
↓
Improved forecasting for energy generation, demand, transmission

→

Operational requirements
↓
Control, operations
↓
More efficient use of renewables, Cost decreases and improved demand response

Potential Solution

- Monitor and profile usage
  - Power supply/demand profile
- Increase Efficiency
  - Turn on/off systems automatically
  - Consolidate computers
  - Tune various subsystems
- Use Alternative Energy Sources
  - Tune systems to variable energy supplies

Outlet level Building Monitoring

- Designed sensors for power outlet monitoring
  - Based on the Kill-A-Watt design

- Modified sensor with low-power wireless radio
  - Transmits data to strategically placed receivers
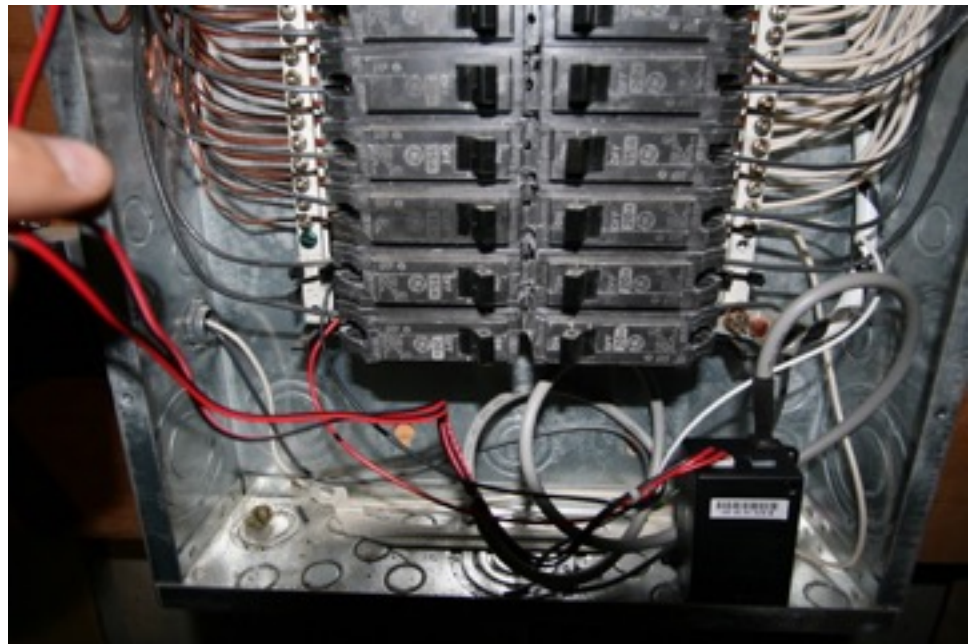 - Use plug computers for receivers

Fine-grained Building Monitoring

- Advantages
  - Accurate, fine-grain data
  - Cheap money-wise to build
  - Able to put them everywhere

- Disadvantage
 - Expensive time-wise to build

Meter level Monitoring

- Install on main panel

Analyzing the data

- Energy monitors / sensors provide real-time usage data
  - Smart meters:
  - Building monitoring systems (BMS) data from office / commercial buildings

- Modeling, Analytics and Prediction
  - Use statistical techniques, machine learning and modeling to gain deep insights
    - Which homes have inefficient furnaces, heaters, dryers? Are you wasting energy in your home?
    - Is an office building's air condition schedule aligned with occupancy patterns?
   - When will the aggregate load or transmission load peak?
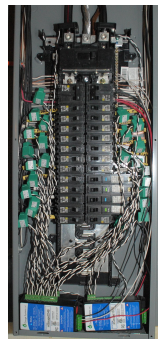
Deployments in Western MA

Use Renewables

- Rooftop Solar, Solar Thermal (to heat water)
- Design predictive analytics to model and forecast energy generation from renewables
    - Use machine learning and NWS weather forecasts to predict solar and wind generation
- Benefits: Better forecasts of near-term generation; "Sunny load" scheduling
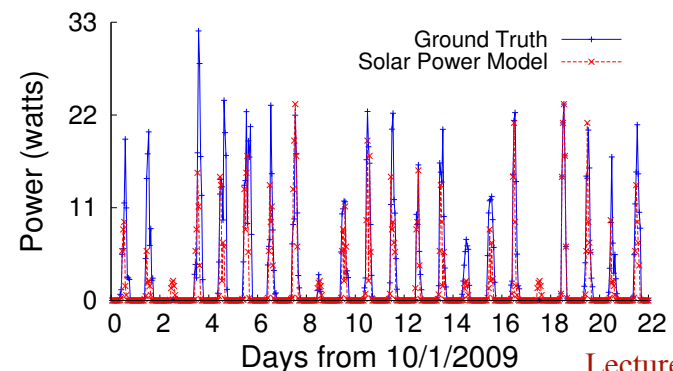
People: Feedback and Incentives

- How to exploit big data to motivate consumers to be more energy efficient?
  - What incentives work across different demographics?
  - Deployments + user studies
- Big data methods can reveal insights into usage patterns, waste, efficiency opportunities
  - Smart phone as an engagement tool to deliver big data insights to end-users
    - Provide highly personalized recommendations, solicit user inputs, motivate users
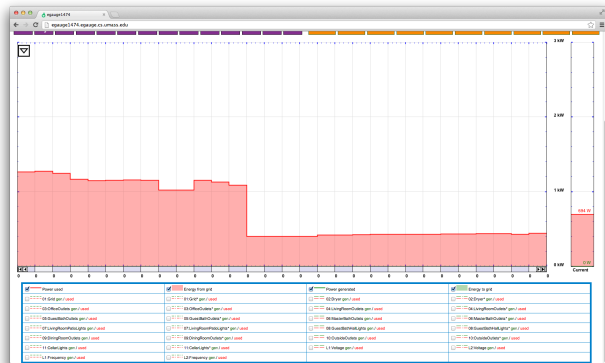
Summary

- Pervasive computing
  - Application example
  - Sensor node and platform design

- Greening of computing
  - Design of energy-efficient hardware & software

- Computing for greening
  - Use of IT for monitoring
  - Use of intelligent software for power management
  - Forecasting for renewable energy harvesting