

# Report from Networking Breakout Groups

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# What is our mandate?

## **Reducing energy use “of” ICT or can it include “by” ICT?**

- Sensor networks are very useful for “by” ICT energy savings
- We think it is fair to discuss “by” ICT if it has network issues

# Topics

- **Problems**
- **Directions**
- **Thoughts towards a science**

# Problems

## Need to address interdependency of power and performance

- **How to do energy efficient data acquisition (sensor nets)?**
  - Applies to extending battery life
- **How to provide a service when a lot of nodes are asleep?**
  - Applies also to subcomponents asleep within a system

### Key issue:

- **Communication is expensive (wireless, sensors)**
  - Can we live in an inconsistent world?
  - Can do approximate queries that fall within an application tolerance or granularity?

# Problems (continued)

## Need new ways of designing networks including protocols #1

- **Current protocols not designed for energy efficiency**
  - For example, keep-alives are expensive
  - Protocols designed from clean slate
    - Get away from keep-alives
    - Get away from device-specific hacks
    - Redesign end-to-end protocols that can deal with components that go into standby mode

### Key issue:

- **Need to define energy metrics**
  - Joules / byte may be too simplistic
  - Metrics in the networks: what would be network architecture to optimize power?

# Problems (continued)

## Need new ways of designing networks including protocols #2

- **Cross layer and system optimization**
  - Computation versus communications trade-offs
  - Latency versus energy trade-offs
  - Send power to me, or bits to me?

### Key issue:

- **Hidden energy costs are unknown**
  - Simply put, need to know what inputs to use for models

# Problems (continued)

## Need new ways for energy-aware network design and traffic engineering

- **Are we better off using 50% of processing power 100% of time or 100% of processing power 50% the time?**
  - Question arises in many contexts: multicore, data centers, etc
  - Answer depends on many things...
    - For example, relationship between processing power and energy consumption
  - **Can we design chips/processors that have “optimal” processing-energy relation?**
    - Design process in iterations.

### Key issue:

- **Need to understand energy-performance models**
- **New combinatorial optimization problem**

# Problems (continued)

## Need to be able to do a cost-benefit analysis

- **Again... hidden costs need to be known**
- **Could allow for a game theoretic approach**
  - For example, nodes automatically take action as appropriate
- **Might support a more collaborative approach**
  - Avoid one-to-one, notion of “recycle bits”

 **Common theme**



# Problems (continued)

## Need to also consider...

- **User interfaces**
  - How to make stuff work energy smart
- **Regulatory / Economic / Social Behavior issues**

# Problems (continued)

## Foundations for wireless/sensor/battery powered networks

- Energy complexity as a metric
- Capacity of a wireless network and its relationship to power
- Models need to strike a balance between tractability and applicability to real world.
- Multi-radio platform and the use of heterogeneous radios to save energy

# Directions

## **A direction is tools and formal models to study trade-offs**

- **Experimental test beds are being built and made available**
  - For example, sensorLab at Harvard
- **Simulation models exist for sensor networks**
  - For example, TOSSIM at Berkeley
- **Some previous work has been done in formal models**
  - To study performance-energy trade-offs
  - Some examples were noted
- **New formal techniques need to be defined**
  - For example, would communicating FSMs work?

# Thoughts towards a science

## Being able to truly measure will lead to science (and savings)

- **Is modeling energy use as an optimization problem “it”?**
  - Or, is this just a tip of the iceberg?
  - Do we need an entirely new/different mindset?
  - Do we need a model for parallelizability?
  - What is the right model for coming-up with new protocols?
- **Need a framework of models**
  - To understand interactions of time, space, and energy

### **Developing models is key to a science of power management**

- Understand how things really work (match theory to reality)
- Understand hidden costs