Energy Consumption Trade-offs in Sensor Networks

Cintia B. Margi, Katia Obraczka, Roberto Manduchi
Internetworking Research Group, Computer Engineering Department
University of California Santa Cruz
contact: cintia@soe.ucsc.edu

Background

- MANETs (multi-hop ad-hoc networks)
  - No fixed infrastructure
  - Nodes are typically battery operated
- Sensor Networks
  - Special case of MANETs
  - Mobility: none or restricted (most cases)
  - Resource constrained
  - Varying characteristics:
    - Anemic vs. powerful sensors
    - Flat vs. hierarchical deployments

Motivation:

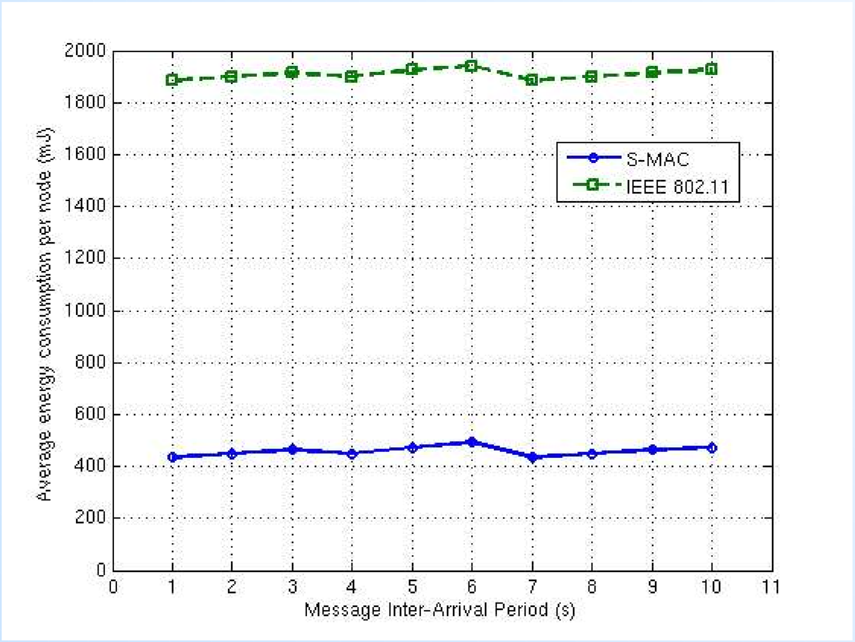
- Understand energy trade-offs between computation and communication
- Assumption: communication dominates energy consumption.
- Heterogeneity in sensor networks

Energy Consumption Model for Communications:

- Explicitly accounts for low-power radio modes.
- Considers the different energy costs associated with each one of the possible radio states.
- Energy spent while in a given radio state *y* is:
  - $E_y = P_y * T_y$
    - $P_y = V * i_y$
    - tx: $T_y = PacketSize/TransmissionRate$
    - Otherwise, use a timer
- Implemented in GloMoSim and QualNet.

Simulation Results: **802.11 vs. S-MAC**

- 50 nodes
- low power radio (TR1000)
- CBR with 10 sources, 380 bytes
- routing: AODV
- Duration: 150s



Summary of Accomplishments:

- Simple energy model for communication.
- Implemented at GloMoSim & QualNet.
- Instrumentation provides complete energy and time accounting per radio state.
- Useful tool to evaluate and understand power-aware protocols.
- References:

- "Instrumenting Network Simulators for Evaluating Energy Consumption in Power-Aware Ad-Hoc Network Protocols", C.B. Margi and K. Obraczka, IEEE/ACM MASCOTS 2004.
- "Modeling Energy Consumption in Single-Hop IEEE 802.11 Ad Hoc Networks", M.M. Carvalho, C.B. Margi, K. Obraczka, and J.J. Garcia-Luna-Aceves, IEEE ICCCN 2004.

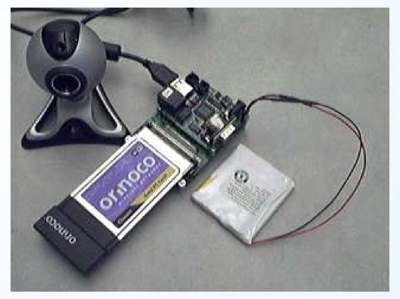
Energy Consumption Model for Processing and Sensing:

Approach:

- Energy cost based on tasks.
- Energy measurements.
- Battery discharge behavior.

Energy consumption measurements on Laptops:

- Observe battery discharge rate using ACPI.
- Dell laptops: Pentium III 750Mhz, 256 MB RAM, 20 GB disk, Lithium-Ion battery.
- OS: Linux (Debian)
- Set of experiments:
  - baseline system: 10.200 W
  - processing (FFT): 25.047W
  - disk access (dbench): 13.430 W
  - network transmission (Iperf):22.289 W:
  - network reception (Iperf): 16.101 W



Crossbow Stargate with Orinoco wireless card and Logitech QuickCam.

Energy consumption measurements onStargate:

- Measure current drained by system.
- Crossbow Stargate: XScale PXA255 CPU (400 MHz),32MB flash memory and 64MB SDRAM. Mainboard also has PCMCIA and Compact Flash connectors, while daughter board has Ethernet, USB and serial connectors. We use Orinoco Gold 802.11b PCMCIA wireless card and a Logitech QuickCam Pro 4000 webcam (640x480pixels)
- OS: Linux (Stargate 7.3)

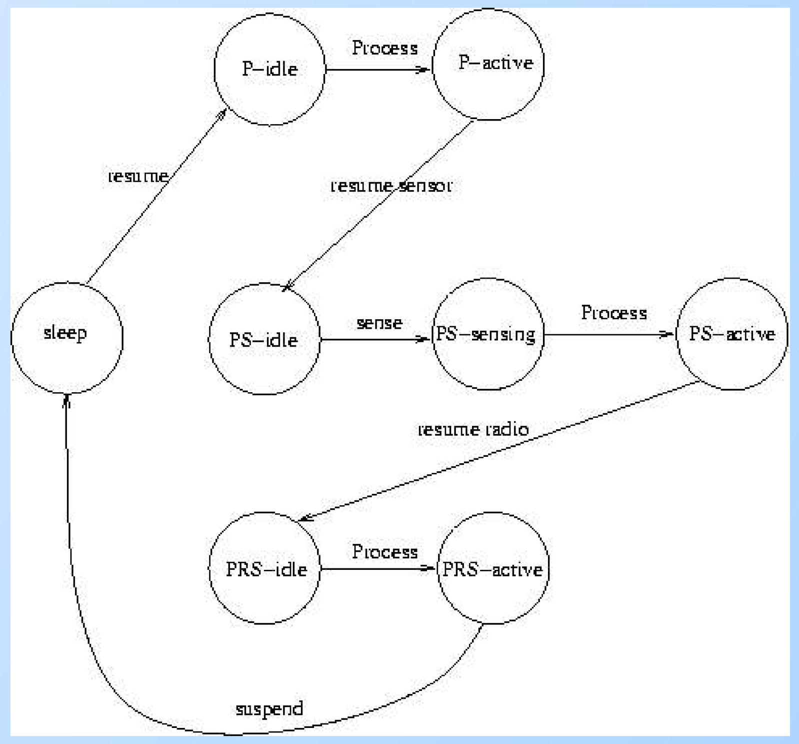
Energy Consumption benchmark:

- consists of a set of basic operationsthat are representative of tasks performed by visual sensor nodes.

State	Processor	Sensor	Radio	Storage	Power (W)
Sleep	Sleep	Sleep	Sleep	Sleep	0.34
P-idle	Idle	Sleep	Sleep	Idle	0.67
P-active	Active	Sleep	Sleep	Idle	1.9
PR-idle	Idle	Sleep	Idle	Idle	1.51
PR-active	Active	Sleep	Idle	Idle	2.8
PR-rx	Idle	Sleep	Active	Idle	2.95
PR-tx	Idle	Sleep	Active	Idle	2.73
PRS-idle	Idle	Idle	Idle	Idle	2.38
PRS-active	Active	Idle	Idle	Idle	3.68
PRS-rx	Idle	Idle	Rx	Idle	3.5
PRS-tx	Idle	Idle	Tx	Idle	3.7
PS-idle	Idle	Idle	Sleep	Idle	1.53
PS-active	Active	Idle	Sleep	Idle	2.8

Energy Consumption Modeling and Prediction:

- Considering the states(presented in the table above and the actions that can trigger state changes (suspend, wake up, activate sensor, receive data, transmit data, process, read, write), we can determine the associated state diagram.
- From the state diagram and probabilities of transitions, we can calculate the expected energy consumption of a node.



State diagram for a scenario where the node is initially on sleep state, then it wakes up, decides to take a picture, apply some computer vision algorithms, then turn on its wireless card to check if there is any messages from its neighbors, and since none was received, it goes back to sleep mode.