Ecological Applications of Wireless Sensor Networks

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Boston University Summer 2006 Photonics REU: Final Report

This Presentation

- Project Goals
- Wireless Sensor Networks
- Motes
  - Attenuation
  - Calibration
- Field Tests
- Photosynthesis
- Future Work

Project Goals

- Measure ecological data with wireless sensor networks
  - Software
  - Hardware
  - Data Collection

- Show that wireless sensor networks are better than conventional methods for evaluating photosynthesis

Wireless Sensor Networks

- Use small, self-contained sensors called motes
- Data sent with radio, laser, infrared
- Ad hoc network
  - Each mote becomes aware of nearby motes and form a network
  - Self forming

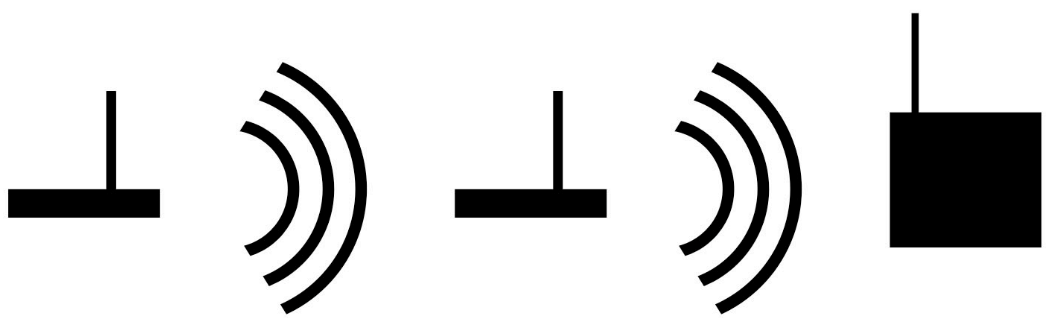
Hop Scenarios

Single-Hop

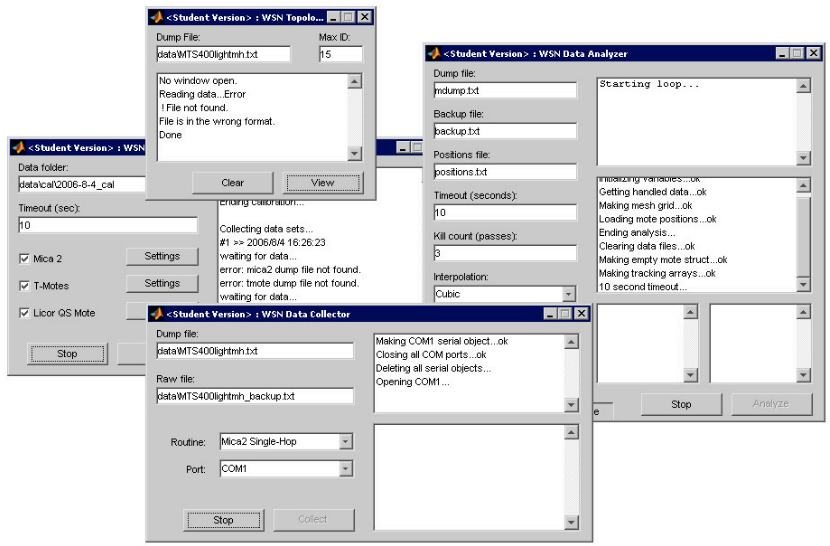
data is sent directly from a mote to the base station (limited range)

Multi-Hop

data is passed from a mote to other motes and then to the base station (long range)

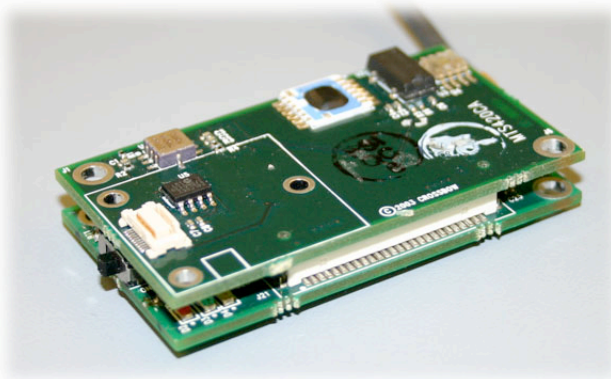


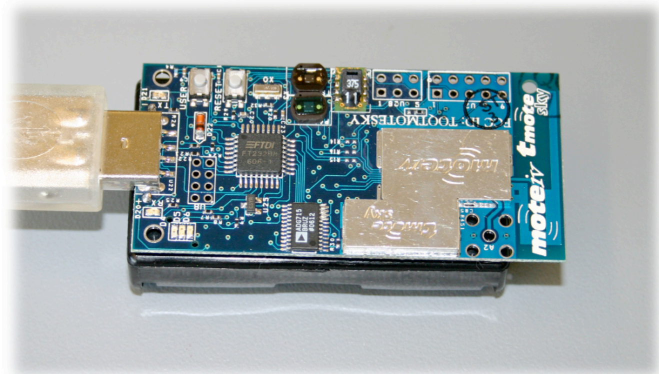
Collection and Analysis



- MATLAB applications package
  - Data collectors
  - Calibrator
  - Real-time and post analyzers
  - Engineering unit converters

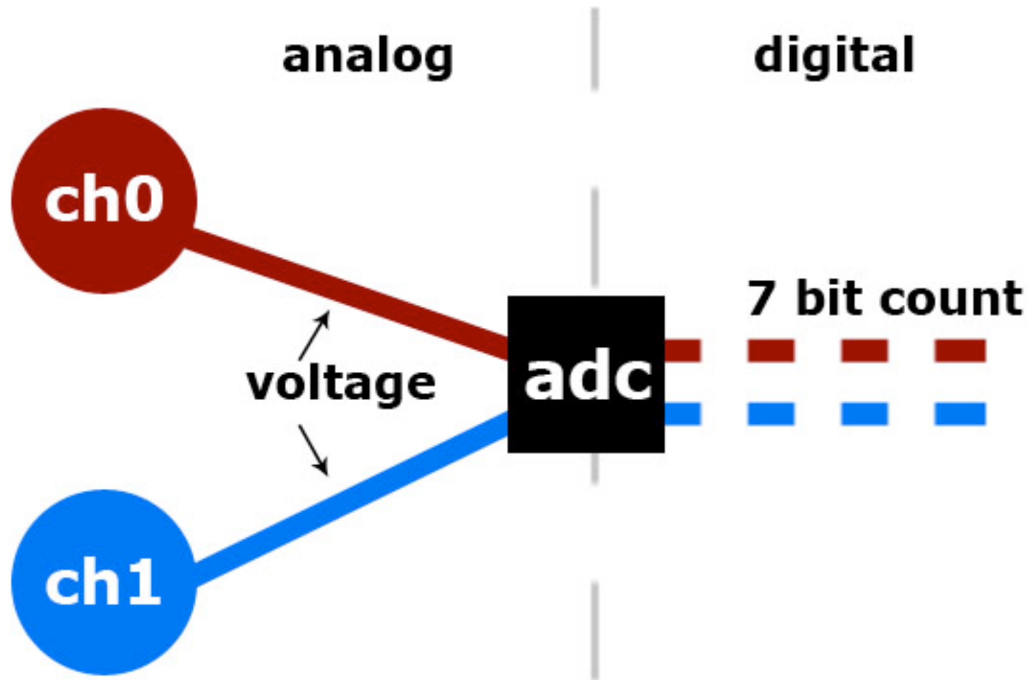
Our Motes





	Mica2	Tmote Sky
Light Intensity	X	X
Temperature	X	X
Humidity	X	X
Pressure	X	
Acceleration	X	
Low Power Mode	X	X
Our Uses:	Large scale light collection	Bat barn animal study

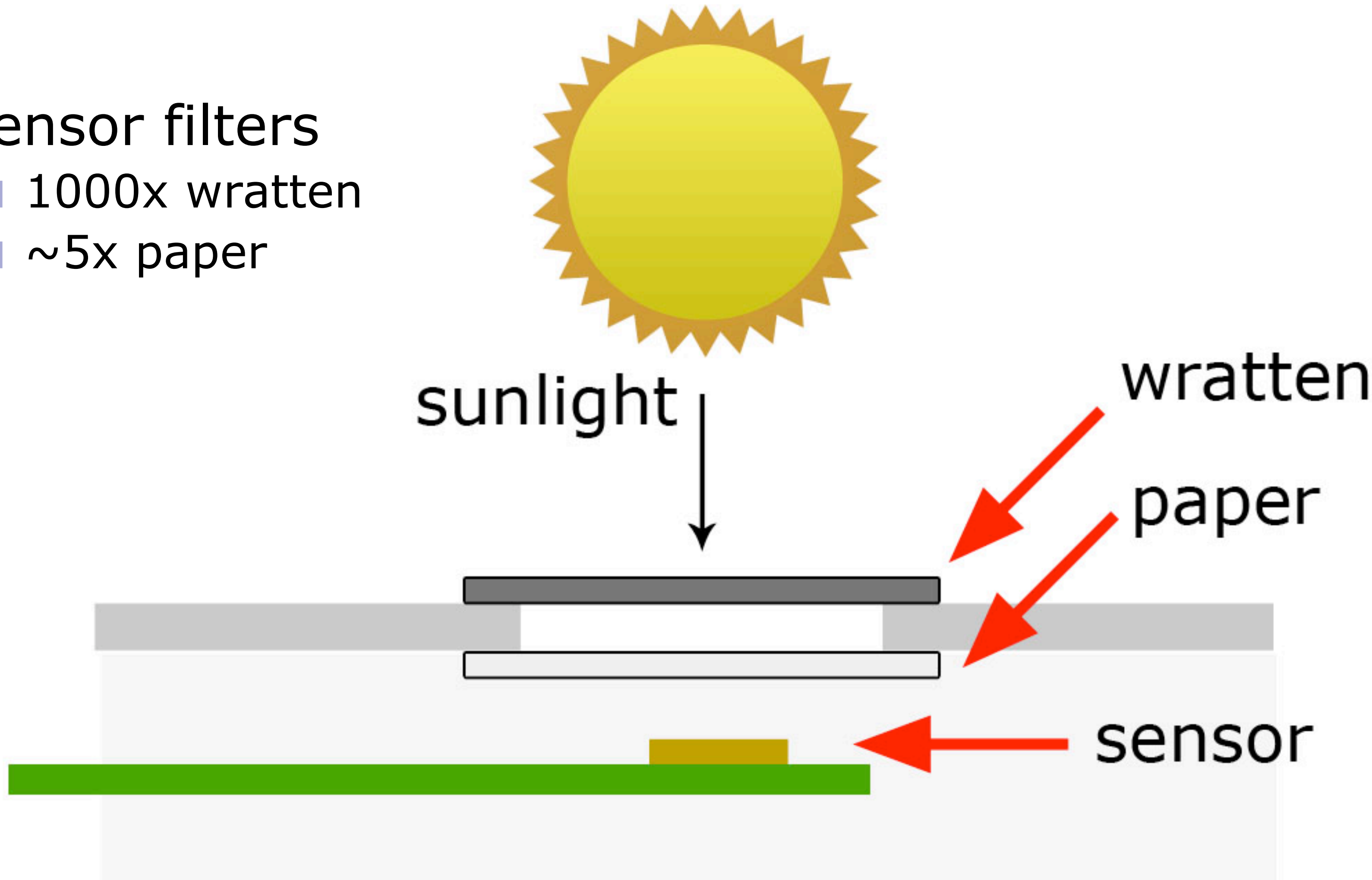
Light Sensor



- Two 7-bit counts
  - If ch0 or ch1 count > 1111111
    - Overflow
    - Sensor saturates

Sensor Attenuation

- Sensor filters
  - 1000x wratten
  - ~5x paper



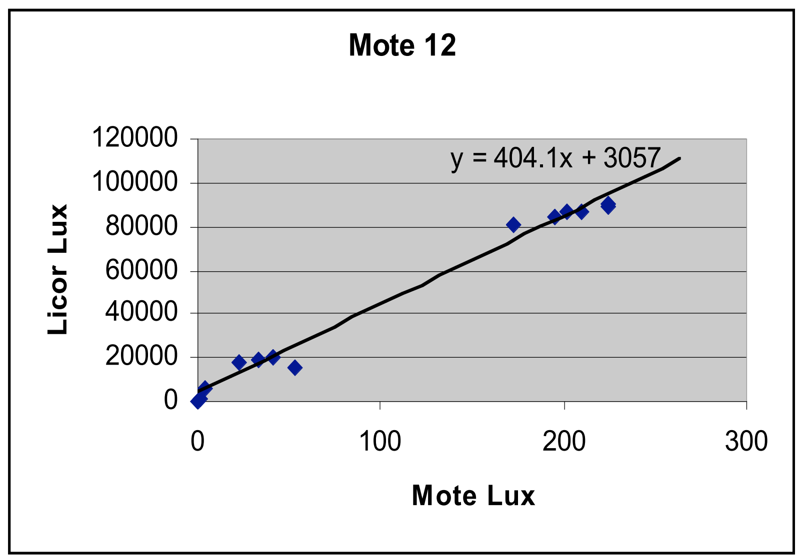
Calibration

- Heavy attenuation requires calibration
- Difficult to calibrate for large range of light
  - 12 hour test (sunrise to sunset)
- Calibrate each mote against a very accurate control light sensor
  - ADC mote

Calibration Solution

- Voltmeter to measure control sensor
- Log data by hand
- Linear calibration equation for each mote

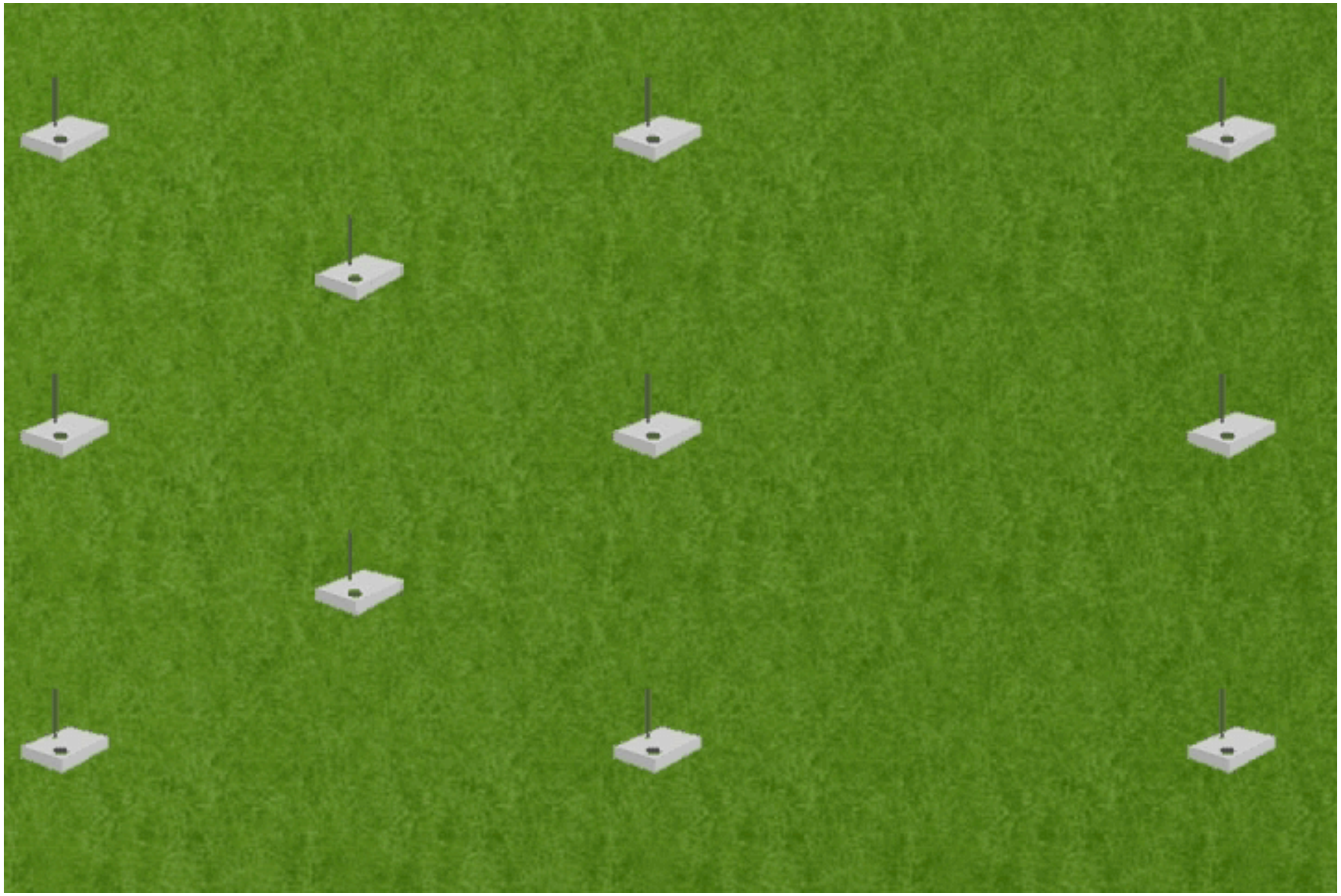
	A	B	C	D	E	F	G	H	I
1		1	2	6	12	13	15	licor	v
2	table	0	0	0	0	0	0	499.664	
3	window	0.46	0.46	0.92	0.92	0.46	0.46	1.32E+03	
4	shade	5.06	4.6	4.6	4.6	4.14	4.14	5.59E+03	
5	sun	279.45	250.01	264.73	264.73	264.73			
6									
7	outside	250.01	216.89	235.29	224.25	180.09	235.29	88576.8	1.95
8		250.01	224.25	235.29	224.25	187.45	235.29	90393.76	1.99
9		28.29	19.55	39.33	53.13	15.87	43.01	15444.16	0.34
10		235.29	202.17	224.25	209.53	172.73	224.25	86305.6	1.9
11		67.85	64.17	50.37	41.17	35.65	39.33	20440.8	0.45
12		224.25	194.81	216.89	202.17	165.37	216.89	87214.08	1.92
13			41.17					22712	0.5
14		43.01	33.81	41.17	33.81	31.97	35.65	19532.32	0.43
15		216.89	187.45	202.17	194.81	158.01	202.17	84034.4	1.85
16		235.29	180.09	180.09	172.73	165.37	143.29	81308.96	1.79
17		30.13	24.61	31.97	22.17	64.17	26.45	18169.6	0.4
18								0	



Open Field Test

- 11 Mica2 motes
  - Record light intensity
  - Multi-hop scheme
- Video
  - Mote layout
  - Animated plots
    - Contour plot
    - Surfaced plot

Video



Static Photosynthesis Models

- Light intensity is only independent variable
- Input parameters dependent upon species

Non-rectangular (Peri et al.):

$$P(h) = \frac{P_{\max} + \alpha h - \sqrt{(P_{\max} + \alpha h)^2 - 4\theta\alpha P_{\max}}}{2\theta}$$

Rectangular $\theta = 0$ (Sullivan et al.):

$$P(h) = \frac{\alpha h P_{\max}}{\alpha h + P_{\max}}$$

h - light

$P_{\max}$ - maximum photosynthetic rate at saturation

α - initial slope of the light-response curve

θ - curvature indicator

Dynamic Photosynthesis Model

- Dynamic equation varies with time

$$P(t,h) = P_{t-1} + (P_t - P_{t-1})e^{-t\tau}$$

- Accounts for increases and decreases in light
- Utilizes predicted steady-state values from the previous models
- (Naumburg et al.)


Conventional Photosynthesis Analysis


WSN Photosynthesis Analysis

Future Work

- Bat barn field test
  - Collect environmental data (light, temp, hum.)
- Get better calibrations
- Apply photosynthesis equations to light data
- Simulate conventional methods with WSN light data
  - Evaluate WSN effectiveness

Summary

- Wireless sensor networks collect data easily and efficiently at high resolutions
  - Useful in ecological studies
- Sensors must be adjusted to suit the testing environment
  - Attenuation
  - Calibration
- Field tests don't always go as planned
  - Murphy's law
- Photosynthesis equations should be better behaved with WSN data

We would like to thank the NSF,
Boston University, and Professor Tom Little
for this great research opportunity.

Any Questions?

References

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- Peri, P.; Moot, D; and McNeail, D. “A canopy photosynthesis model to predict the dry matter production of cocksfoot pastures under varying temperature, nitrogen, and water regimes.” Grass and Forage Science 58: 416-430.
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