Wireless Sensor Network for Habitat Monitoring

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CISTER Summer Seminar Series 2010
16 July 2010

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Outline

- Introduction
- Motivation & Problem Statement
- Great Duck Island Requirements
- System architecture
- System implementation
- Current results
- Discussion
- Conclusion

Introduction

- Habitat and environmental monitoring

Utilizing Sensor Network:

- Long-term data collection
- Difficult/impossible scale

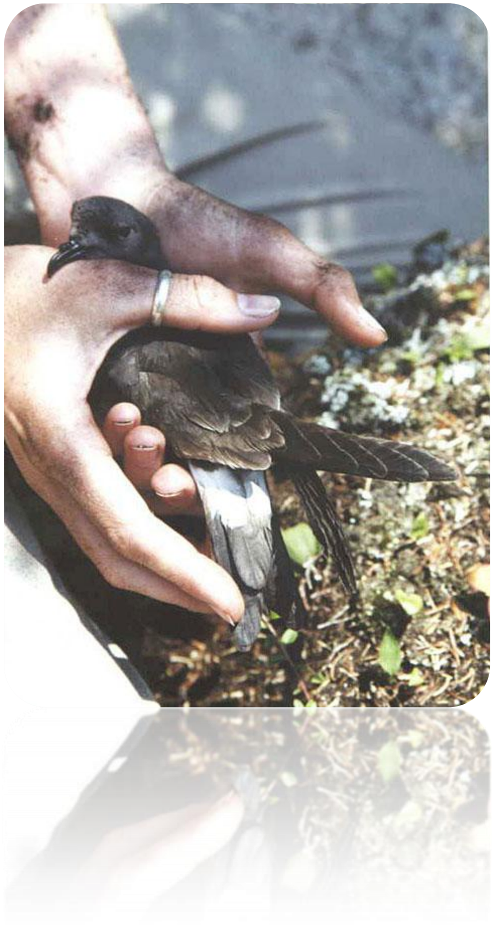
In this work:

- Requirements
- Constraints
- Guidlines

Motivation

Questions:

- What environmental factors make for a good nest?
- How much can they vary?
- What are the occupancy patterns during incubation?
- What environmental changes occurs in the burrows and their surroundings during the breeding season?



Problem Statement

Problems

- Seabird colonies are very sensitive to disturbances
- The impact of human presence can distort results by changing behavioral patterns and destroy sensitive populations
- Repeated disturbance will lead to abandonment of the colony

Solution

- Deployment of a sensor network

Great Duck Island Requirements

- Internet access
  - To support remote interactions with sensor networks
- Hierarchical network
  - To host internet connectivity and database system.
  - To provide connectivity to multiple patches of sensor networks.
- Sensor network longevity
  - Individual field seasons typically vary from 9~12 months

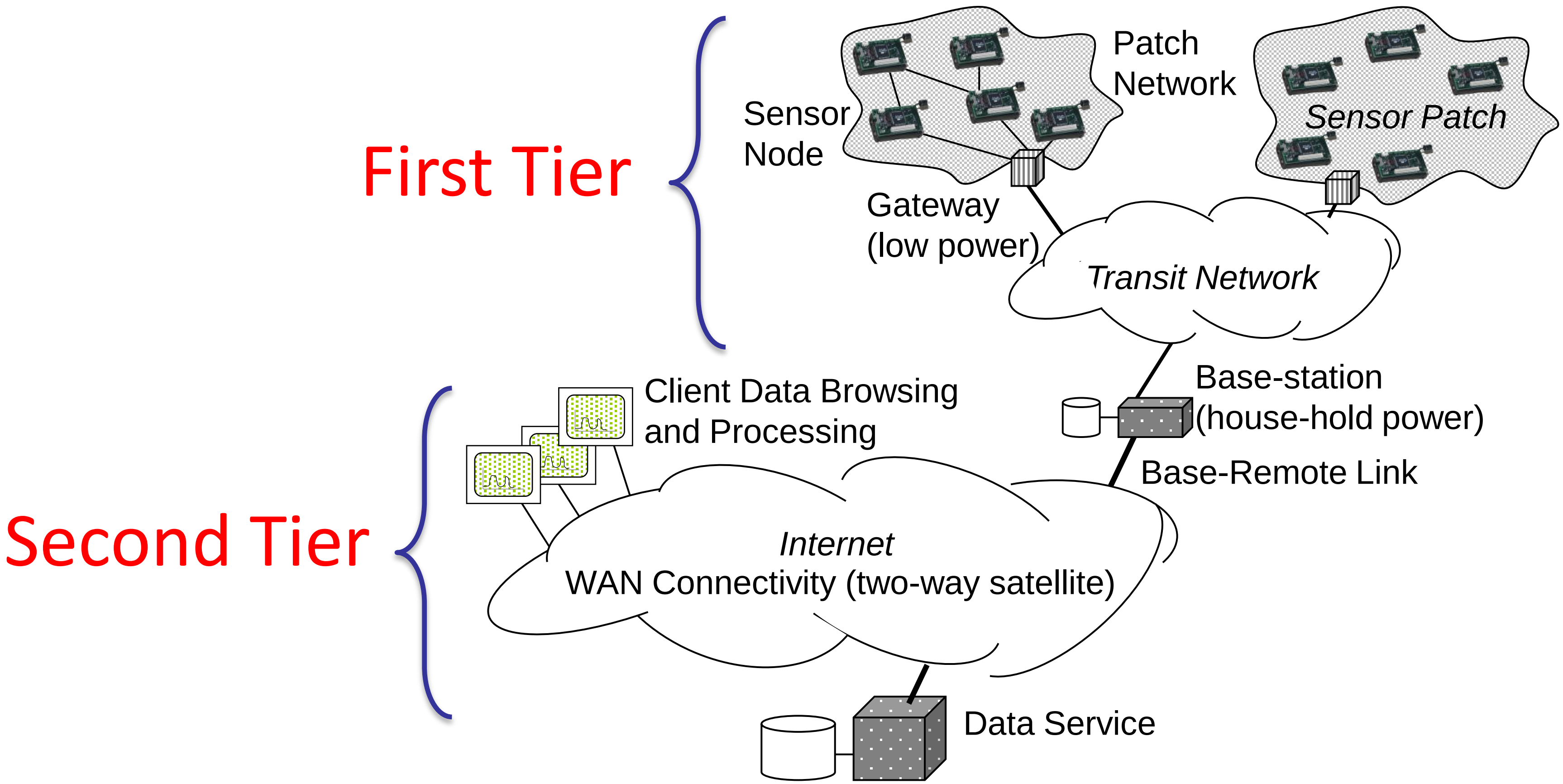
Great Duck Island Requirements

- Operating off-the-grid
  - Every level of the network must operate with bounded energy supplies.
- Management at-a-distance
  - To zero on-site presence for maintenance and administration during the field season
- Inconspicuous operating
  - It should not disrupt the natural processes or behaviors under study.

Great Duck Island Requirements

- System behaviour
  - sensor networks should present stable, predictable, and repeatable behavior whenever possible.
- In-situ interactions
  - Local interactions are required during initial deployment, during maintenance tasks, as well as during on-site visits.
- Sensors and sampling
  - The ability to sense light, temperature, infrared, relative humidity, and barometric pressure is essential.
- Data archiving
  - Archiving sensor readings for off-line data mining and analysis is essential

System Architecture

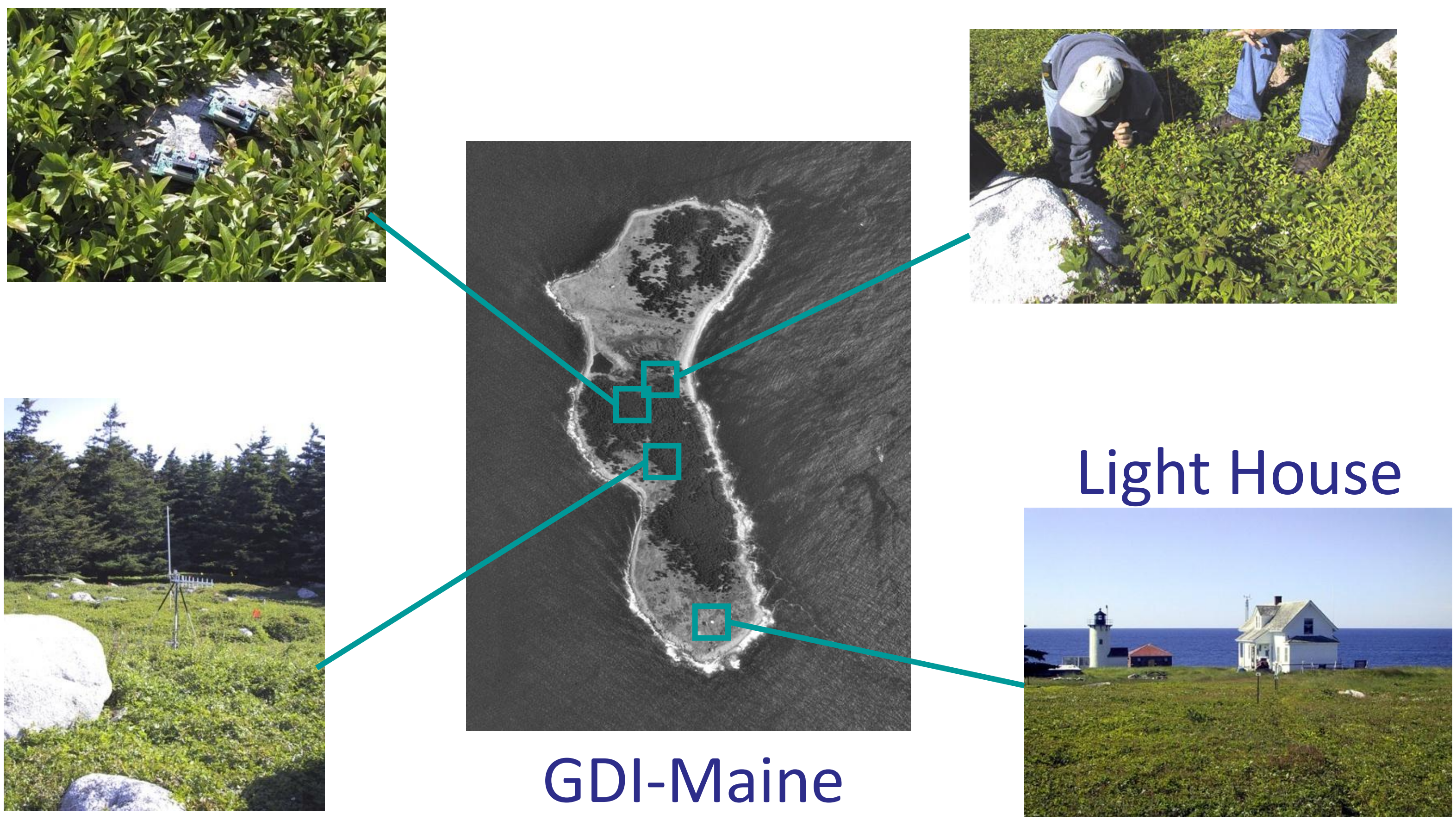


- Database replicas:
  - store data retrievable by scientists

System Architecture

In case of power outage, each layer should have data persistent storage and provide data management services

- Sensor level: data logging
- Base station: full-fledged relational database service
- Gateways: some database services over limited window of data



System Architecture

- System prefers long-latency of data transfer to data loss
- Users interact with the sensor network data in two ways:
  - Remote: users access the replica of the base station database
    - Allows for easy integration with data analysis and mining tools
    - Provides remote control of the network
  - On-site: users use small PDA-sized device (gizmo) to directly communicate with the sensor patch
    - Provides the users with a fresh set of readings
    - Allows users to interactively control the network parameters
    - Useful during the initial deployment and during re-tasking of the network

Implementation Strategy

- Sensor node
  - Single channel, 916 Mhz radio for bi-directional radio @ 40kps
  - Atmel Atmega 4MHz micro-controller
  - 512KB flash RAM
  - 2 AA batteries (~2.5Ah), DC boost converter (maintain voltage)

- Sensor board
  - Mica weather board includes temperature, photoresistor, barometric pressure, humidity, and passive infrared (thermopile) sensors.
  - The sensors are chosen based on
    - high interchangeability (less than 3%)
    - high accuracy (within 3% of actual value)
    - shorter startup time

Implementation Strategy

- Energy budget
  - Limited Resource (2 AA batteries)
  - Estimated supply of 2200 mAh at 3 volts
  - Each node has 8.148 mAh per day (9 months)
  - Sleep current 30 to 50 uA (results in 6.9 mAh/day for tasks)
  - Processor draws apx 5 mA => can run at most 1.4 hours/day
  - Nodes near the gateway will do more forwarding

Operation	nAh
Transmitting a packet	20.000
Receiving a packet	8.000
Operating sensor for 1 sample (analog)	1.080
Operating sensor for 1 sample (digital)	0.347
Reading a sample from the ADC	0.011
EEPROM Read Data	1.111
EEPROM Program/Erase Data	83.333

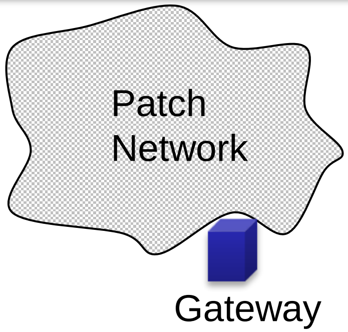
Implementation Strategy

- Sensor deployment
  - Nodes above the ground: Acrylic environmental protective packaging that minimally obstructs sensing functionality

  - Nodes inside burrows: Parylene sealed motes without enclosure
  - Nodes without protective package are less robust

Implementation Strategy

- Patch gateways



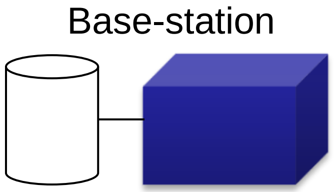
  - Current two designs:
    - An 802.11b single hop with an embedded Linux system (CerfCube ; 12dbi omnidirectional 2.4 GHz)
    - A single hop mote-to-mote network (14dbi directional 916 MHz)

    These two designs differ in communication frequency, power requirements, and software component.

    Currently, only mote solution is used

Implementation Strategy

- Base-station installation



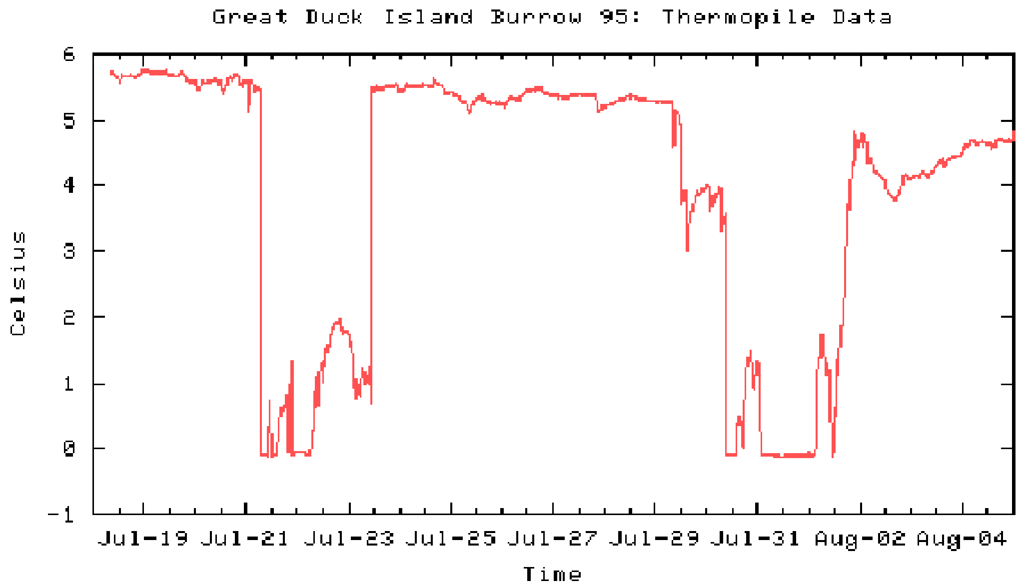
  - Sensor network patches are connected to the Internet through a wide-area link
  - Two way satellite connection that is connected to a laptop (coordinate sensor patches and provide relational database service)
  - Function as turnkey
  - Run unattended

Implementation Strategy

- Database management system
  - Uses Postgres SQL database
  - Stores time-stamped readings from the sensors, health status of individual sensors and metadata
  - GDI database is replicated every 15 minutes over the wide-area satellite link to Postgres database in Berkeley
- User interface
  - Many user interfaces be implemented on top of the sensor network database
  - Gizmo design for local users is not well developed yet

Results

- 32 nodes including 9 in underground burrows
- For 4 weeks
- Raw thermopile data from GDI during 19-day period from 7/18 - 8/5/2002.
- Show difference between ambient temperature and the object in the thermopile's field of view.



Discussion

- All system components must operate in accordance with the system’s power budget

- In a running system, the energy budget must be divided amongst several system services:
  - Sensor sampling and data collection
  - Routing and communications
  - Network re-tasking
  - Health and status monitoring
  - Some other application specific services.

Discussion

- Data sampling and collection
  - By analyzing the requirements we can place a bound on the energy spent on data acquisition
  - Trade the cost of data processing and compression against the cost of data transmission

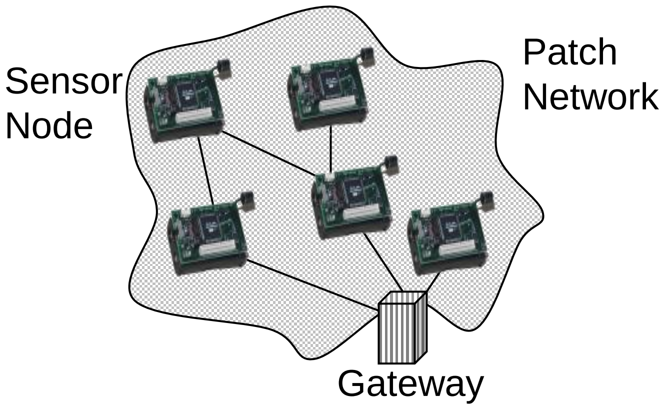
Compression algorithm	Huffman (pack)	Lempel-Ziv (gzip)	Burrow-Wheeler (bzip2)	Uncompressed
8-bit sample	1128	611	681	1365
10-bit sample	1827	1404	1480	1707
16-bit sample	2074	1263	1193	2730
8-bit difference	347	324	298	1365
10-bit difference	936	911	848	1707
16-bit difference	839	755	769	2730

Discussion

- Communications
  - Power efficient communication must include a set of routing algorithms, media access algorithms, and managed hardware access.
  - Most efficient for low duty cycle sensor networks is to simply broadcasting data to a gateway during scheduled communication period. (single hop)
  - Multi-hop scheduled protocol must be used for hard to reach research locations that are beyond the range of a single wireless broadcast from mote to gateway, and two possible strategies are:
    - Scheduled communication
    - Low power MAC protocol

Discussion

•Routing / Communication



- Approach proposed for scheduled communication:
  - Determine routing tree
  - Each gate is assigned a level based on the tree
  - Each level transmits to the next and returns to sleep
  - Process continues until all level have completed transmission
  - The entire network returns to sleep mode
  - The process repeats itself at a specified point in the future

Discussion

- Network re-tasking
  - Adjust the functionality of individual nodes
    - Simple parameter, such as scalar parameters, may be adjusted through the application manager
    - Complex functionality adjustment may be implemented through virtual machines like Mate or reprogramming

- Health and status monitoring
  - Health and status messages sent to the gateway can be used to infer the validity of the mote's sensor reading and also for re-tasking
  - Including battery voltage level in transmitted sensor reading helps remote analysis of node failures

Conclusion

- Habitat and environmental monitoring represent an important class of sensor network applications
- Defined system requirements for habitat monitoring
- Tight energy bounds and the need for predictable operation guide the development of application architecture and services

Thank you!