Environmental Sensor Networks of Past, Present and Future

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Overview

As deployments grow, new challenges arise.
As deployments succeed, new data needs arise.

• Intro to long-term environmental monitoring with WSNs
• Maintaining network health
• Accurate sample timing
• Dealing with data growth
Long-Term Monitoring

- Interaction between abiotic factors and soil animals
- Soil’s role in global CO2 cycle
- Capture effects that are otherwise difficult or impossible to observe.

Temperature (°C)

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WSNs

- Network of many low-power sensing nodes.
- Radio-equipped
- Monitoring soil temperature and moisture
- Low-power wake-up
- Routing logic at base station
- Nodes buffer data for periodic downloads from network

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EWSN Challenges

• Lifetime bounded by battery capacity and duty-cycle
• Limited processing power
• Limited communications range
• Limited storage
• Harsh operating conditions
• Accessibility
Our Deployments

Size of LUYF Dataset

Hardware:
- MicaZ motes
- Watermark soil moisture sensor

Architecture:
- Koala Download
- 2-Phase Data Loading
- Online Monitoring

Samples (Millions)

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Network Health
Network Health I

Commercial Data Loggers

- Collect data from external sensors
- Log to memory
- Researcher collects data
Network Health I

Commercial Data Loggers

- Collect data from external sensors
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If a data-logger fails in a forest and nobody’s around to hear it, how do you write the paper?

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Network Health II

Single-Hop Networks (Jug Bay, Leakin, Olin I)

- Most problems were physical failures/damage.
- Internal sensors indicate trouble (humidity)
Network Health III

• Manual inspection of graphs is fine for small deployments, but difficult for larger deployments

• Automate it!
Network Health III

• Manual inspection of graphs is fine for small deployments, but difficult for larger deployments

• Automate it!
• Complex deployments have “soft” failures as well as “hard” failures

• Example: Radio on-time
Network Health V

- Improvements to download strategies based on log analysis results
- Better visualization of network activity
Accurate Sample Timing

![Graph showing ambient temperature changes over time.](image)
• Mote clocks are not all alike
• Temperature and manufacturing introduce variability
• Reboots reset a mote’s clock to zero
• How do we fix this?
timestamps II

$\text{GTS} = \alpha \times \text{LTS} + \beta$

"\(\alpha\)" (slope) represents Clock-skew

"\(\beta\)" (intercept) represents Node Deployment time

<LTS, GTS> Anchor Points
• Assumes base station clock is reliable

• Assumes that base station contact is roughly as frequent as reboot
What happens when you break these assumptions?
Timestamps V

![Timestamps V Graph]

Nodes and times are represented in the graph. Time is on the x-axis, and nodes are on the y-axis.
Timestamps V

The diagram represents the relationship between nodes and time. It shows different colored horizontal lines indicating the presence of nodes at various times. The axes are labeled as follows:

- **Y-axis (Node)**: Represents different nodes across 5 units.
- **X-axis (Time)**: Represents time from 0 to 6 units.

The lines help visualize the temporal occurrence of each node.
Timestamps V
Timestamps V
Timestamps V
Timestamps V
Data Growth

• Data growth so far has been the result of more motes - Visualization problem.

• What happens when you want to increase the data yield per-mote? Network problem.
Data Growth

- Squeeze the data harder!
- Tune sampling rates to science needs: sample external more often than internal
- Store most samples as change from previous reading rather than absolute reading
Data Growth

- Signals that we measure compress very nicely.
- Increase rate without increasing data in network
Today’s successful deployments lead to tomorrow’s challenges!
Credit

Collaborators

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