Koala

Ultra-Low Power Data Retrieval in Wireless Sensor Networks

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Low Power Probing (LPP)
Flexible Control Protocol (FCP)
Koala
Story
Life Under Your Feet
Dozer

Nicolas Burri, Pascal von Rickenbach, Roger Wattenhofer
ETH Zurich, Switzerland
Repeated Research
Goals

- Permille Duty-cycle
- No clock Synchronization
- Medium Size Networks
- Simplicity
Sleeping
Wake up
Wake up an entire network
Stay up
Neighborhood Discovery
## Recap

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<tr>
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<th>Wake up</th>
<th>Low Power Probing</th>
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<td>Neighborhood Discovery</td>
<td>Flexible Control Protocol</td>
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<td>4</td>
<td>Data Download</td>
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I. Wake up
Low Power Probing
Low Power Listening

Packetized Preamble

LPL Sender

LPL Receiver

CCA Sampling

ACK
Low Power Probing

LPP Sender

Listen

ACK

LPP Receiver

Probe (broadcast)

ACK
How does it work?

Gateway
Performance of LPP

![Graph comparing LPP and LPL over time]
LPP vs LPL

- Probing in LPP is takes in average 26% longer than LPL

  but

- LPP is resilient against RF interference

  and

- LPP generates less noise during wake-up.
2. Stay up
3. Neighborhood Discovery
Two steps

1. Each mote discover its neighbors.

2. The gateway retrieves the neighbor list from each mote using Flexible Control Protocol.
Requirements

• Bounded amount of traffic
• Independent of node density
• Fairness
Solution

• Send beacons using an exponential distribution and

• Suppress the transmission if you receive another beacon before your timer expires.
Problem

- Generating an exponential distribution requires computing the logarithm
- ... which can be approximated using the first term from the Taylor expansion:

\[
\log(x) = (x - 1) - \frac{(x - 1)^2}{2} + \frac{(x - 1)^3}{3} - \frac{(x - 1)^4}{4} \ldots
\]
Flexible Control Protocol
Mote Herding for Tiered Wireless Sensor Networks

Thanos Stathopoulos, Lewis Girod, John Heidemann, Deborah Estrin

UCLA
Centroute
FCP Characteristics

• Fixed header of 3 bytes.
• Source routing for establishing a path.
• Everything is soft-state.
• It’s easy to reply (mote) but more complicated to initiate a connection (usually the gateway).
Path establishment

\[ (G,2):A,B,C \]
\[ (A,5):A,B,C \]
\[ (B,3):A,B,C \]
Path establishment

G → A → B → C

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Data transfer

G ←→ A ←→ B ←→ C

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Flexible Control Protocol

Applications

CTP
Drip
DIP

Unreliable Ephemeral Path
Reliable Ephemeral Path
Unreliable Persistent Path
Reliable Persistent Path

Flexible Control Protocol

Active Message
4. Download
Download

Unreliable Persistent Path

or

Reliable Persistent Path
Unreliable Persistent Path

1. Pick a path.
2. Establish the connection.
3. Request for chunks of data until the desired interval of data is retrieved.
One more thing
Channel Switching

Flexible Control Protocol
Evaluation
What do we want to measure?

- Cost of LPP.
- Performance of the wake up procedure.
- Performance of the download.
- Impact of the channel switching.
Performance of the LPP
TOSSIM

Gains are computed using the Log Distance Path Loss model. Noise is simulated by CPM using meyer-heavy.txt noise trace.
Testbed vs TOSSIM

Testbed vs. simulated topologies

![Graph comparing RSSI values between testbed and simulation](image-url)

- Testbed (24 nodes)
- Simulation (25 nodes)
Impact of channel switching

25-node network, LPP interval of 20 seconds

![Graph showing impact of channel switching with and without channel switching, comparing radio-on time to data size in kilobytes. The graph includes data points and lines indicating the relationship between waiting time and data size for different channel switching scenarios.](image-url)
Performance of Koala

25-node random network, LPP interval of 20 seconds, with channel switching

Duty-cycle vs Data rate [bytes/day/node]

- 512KB (black)
- 128KB (blue)
- 32KB (orange)

Data rate ranges from 0 to 120,000 [bytes/day/node]. Duty-cycle increases from 0% to 0.8%.

Graph shows how duty-cycle changes with varying data rates for different data buffer sizes.
Can we do better?
Overhead
Percentage of time in idle listening.
Future work

• Integration with Flush/RCRT.
• Full LPP compatibility with LPL.
• Improvements in path selection.
Status

- LPP is already in tinyos-2.x-contrib.
- FCP and Koala will follow soon.
- Testing in the field is in progress.
Thanks!
Thanks!
Questions?