Experimental Analysis and Characterization of a Wireless Sensor Network Environment

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Motivation

- Existing testbeds – rare, specialized and costly + **not fully exploited**
  [SensorScope, Mirage, SensLab, WUSTL…]
- **Lack of generic results** – evaluate specific protocol (tested) aspect

Senslab – INRIA Rennes, France
Statistical analysis:

Real world testbed data traces
Obtain insight in the WSN environment itself

Our analysis includes in particular:

- Link properties + correlation with environmental parameters
- How to predict the link quality?
- Network dynamics – neighborhood and link evolution
- How to discard measurement errors?
- Discuss testbed design
WSN testbed
Number of nodes (sinks): 36 (2)
Area: 500m x 300m
Node position: Indoor & outdoor
Node type: Coronis Wavenis
PHY: 868 MHz ISM at 25mW
fast frequency hopping
Protocol details

- **Routing**: Converge cast (gradient virtual coordinates)
- **MAC**: CSMA-CA

- **Duration of the experiment**: 18 days
- **Data packet generation period**: 17 min
- **Neigh. discovery period**: 13 min.
Node data:
- Node ID
- Geographic position (known a priori)

Data packet (successfully received):
- Source node ID
- Neigh. information (ID and RSSI value) - hello
- Sensor measurements (humidity, temp.)
- Timestamp
Create:
- Each pair of nodes => 2 possible link entries (two way)
- Raw data: 16 unidirectional and 280 bidirectional links

Filter:
- Remove entries with small cardinalities (1% of maximum sample size)
- After clean up: NO uni links!
Link quality
**Conclusion:**
- Bidirectional links highly symmetrical

**In addition:**
- RSSI value robust to environmental changes
**Conclusion:**
- Pairs of samples in bidirectional links follow the same distribution

**In addition:**
- RSSI doesn't follow popular distributions but has similar bell shape
Link occurrence ratio

- **def. Link occurrence ratio** - % of the cases where a node responded to *hello* discovery message qualifying a link with an RSSI value

*Example:* Hello rate = 1 packet/s, **period** = 10 s, max = 10 detected = 4 => LOR = 40 %
**Conclusion:**

- A poor link obligatorily means low RSSI (1-40%) – red box
- Each category, different RSSI spreads – green box + red box => RSSI is not directly a good quality estimator

- Individual conclusions are not possible
- The largest RSSI values ~ the stable links.
Network dynamics
Conclusions:

- High variations in neigh. tables => USE reactive approach
- Stable neighbors:
  - high RSSI (> -75dBm) and close distance (d < 0.2•Rmax)
  - or
  - RSSI between -75dBm and -90dBm
- Gray zone (close to threshold) - lack of conclusions
Filtering outliers

- **Goal:** Detect and remove ambiguous and erroneous measures
- **Why?**
- **What is the outlier?**
- **How to detect them?**

\[
x < Q_1 - 1.5 \cdot IQR \quad \lor \quad x > Q_3 + 1.5 \cdot IQR
\]
- **Single outlier**: transitory effect
- **Multiple consecutive outliers (MCO)**: significant temporary change
Global knowledge: Total duration of experiment
* In 90% of the cases – 8 or less MCO

![Cumulative Distribution Function](image)
- **Temporary knowledge:** sliding window of 20 samples
- In 97.5% of the cases – 4 or less MCO per window
Practical impact

- Sliding window for filtering link quality
- Discard inaccurate measures but still reactive
- Applicable to any link quality metric
Conclusion:
- Thorough analysis - insight in WSN environment properties
- Practical method for detecting and discarding outliers
- Insufficient details can seriously limit the analysis reach

Recommendations for a testbed:
- Global network synchronization
- Include PER in discovery and data packets
- Include the RSSI in both directions

Future work:
- Use results in RPL
- Analyze bursty link behavior
Questions?

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