Experimental Analysis and Characterization of a Wireless Sensor Network Environment

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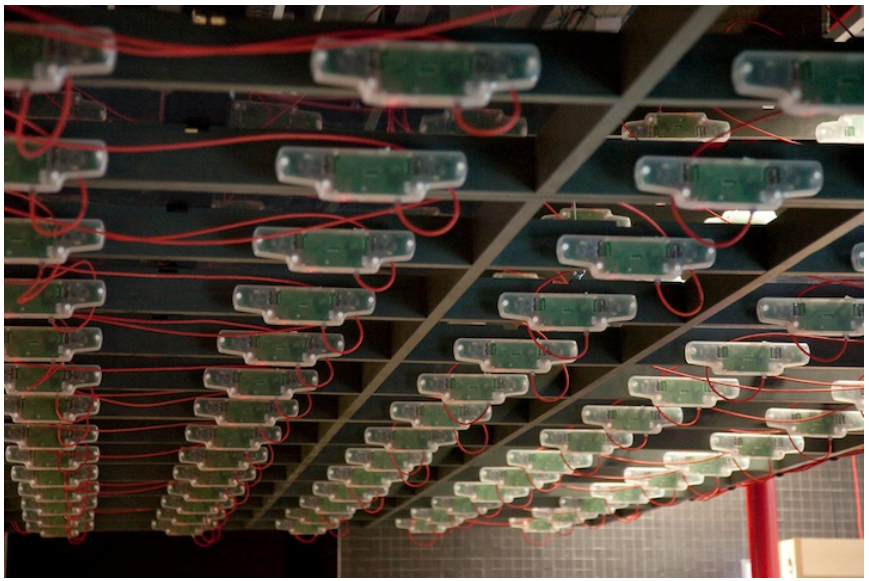
PE-WASUN – Symposium on Evaluation of Wireless Ad Hoc, Sensor, and Ubiquitous Networks
17-21 October 2010 – Bodrum, Turkey

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

One step further

Statistical analysis:

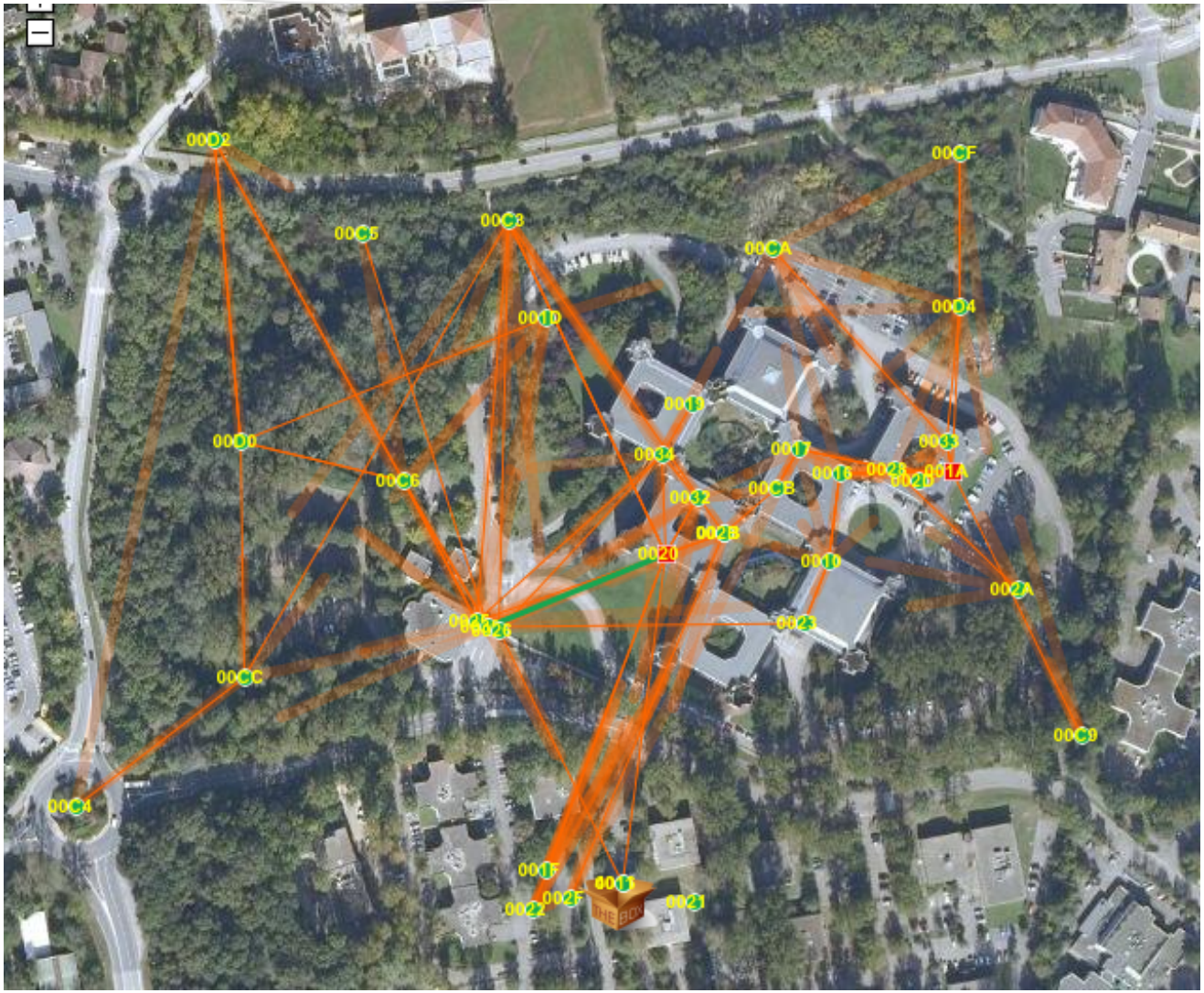
Real world testbed data traces

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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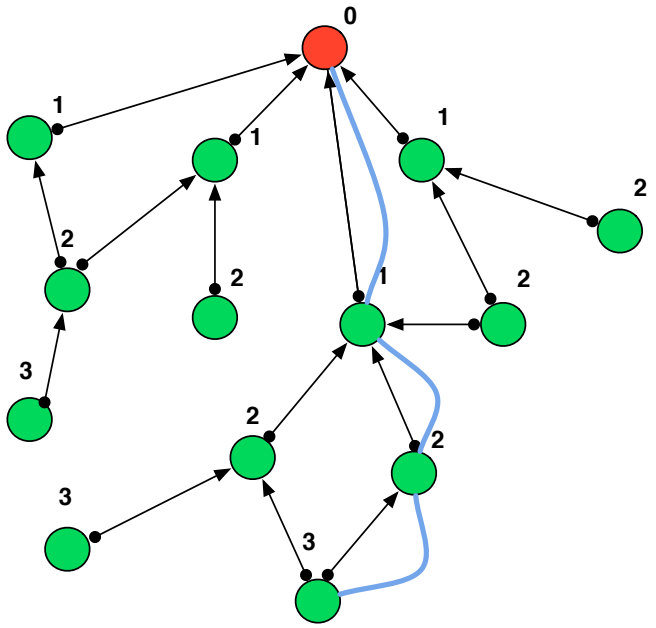
WSN testbed

- **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.



Collected data

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

Link samples

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

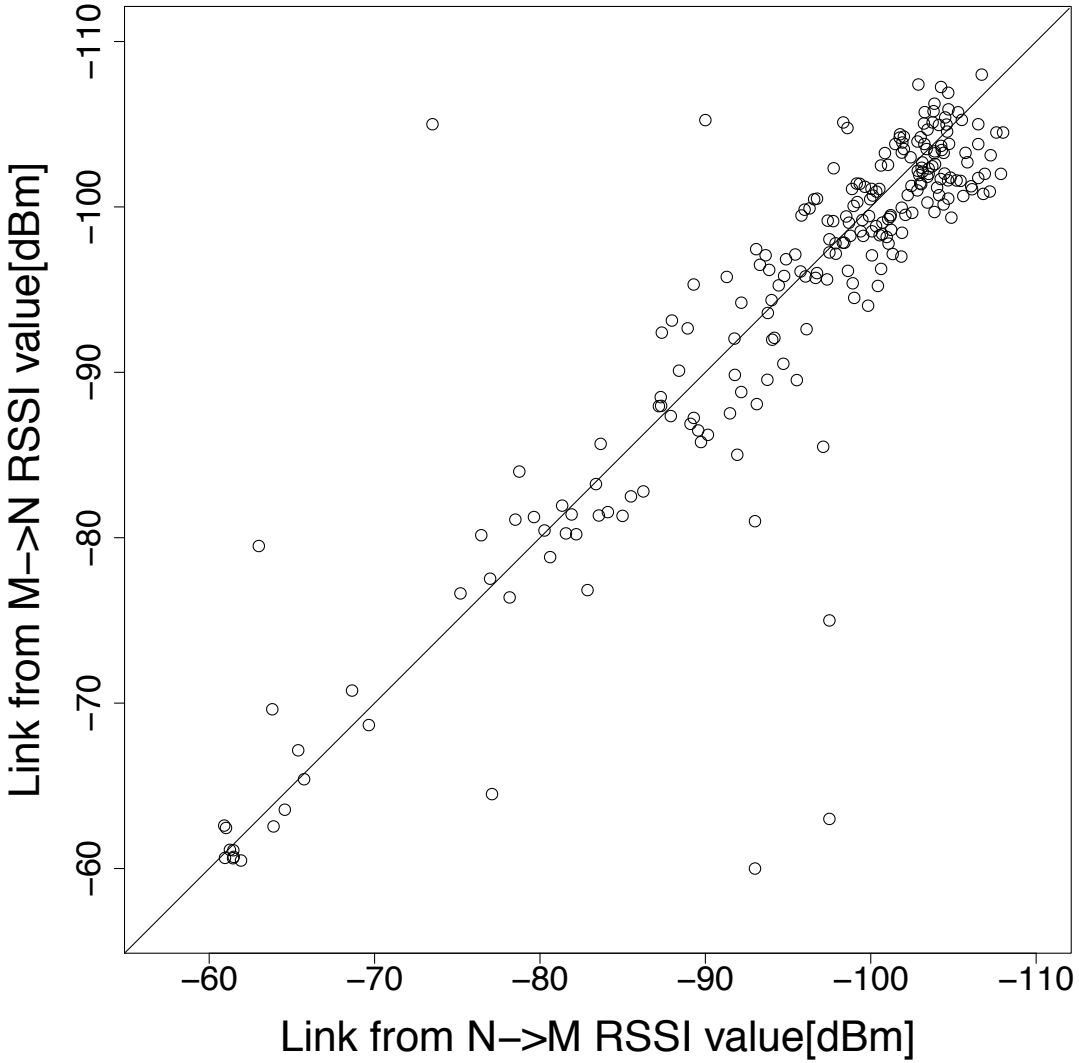
Link properties

Conclusion:

- Bidirectional links highly symmetrical

In addition:

- RSSI value robust to environmental changes



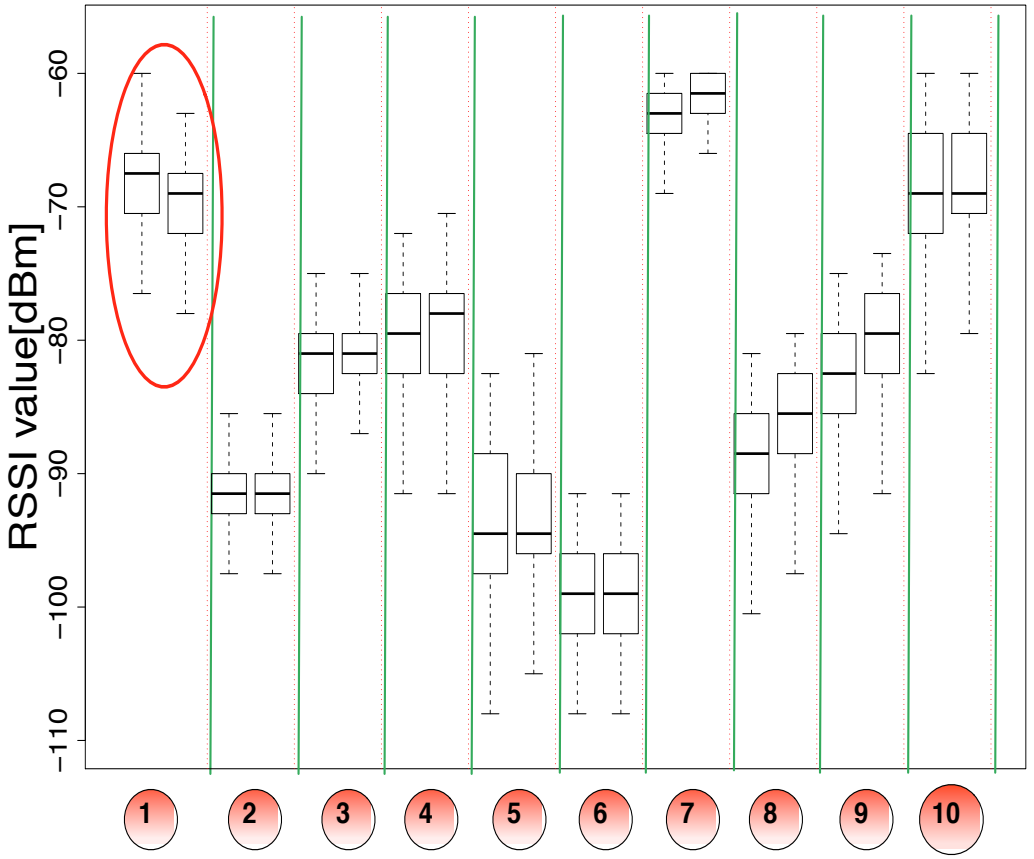
Link properties

Conclusion:

- Pairs of samples in bidirectional links follow the same distribution

In addition:

- RSSI doesn't follow popular distributions **but** has similar bell shape

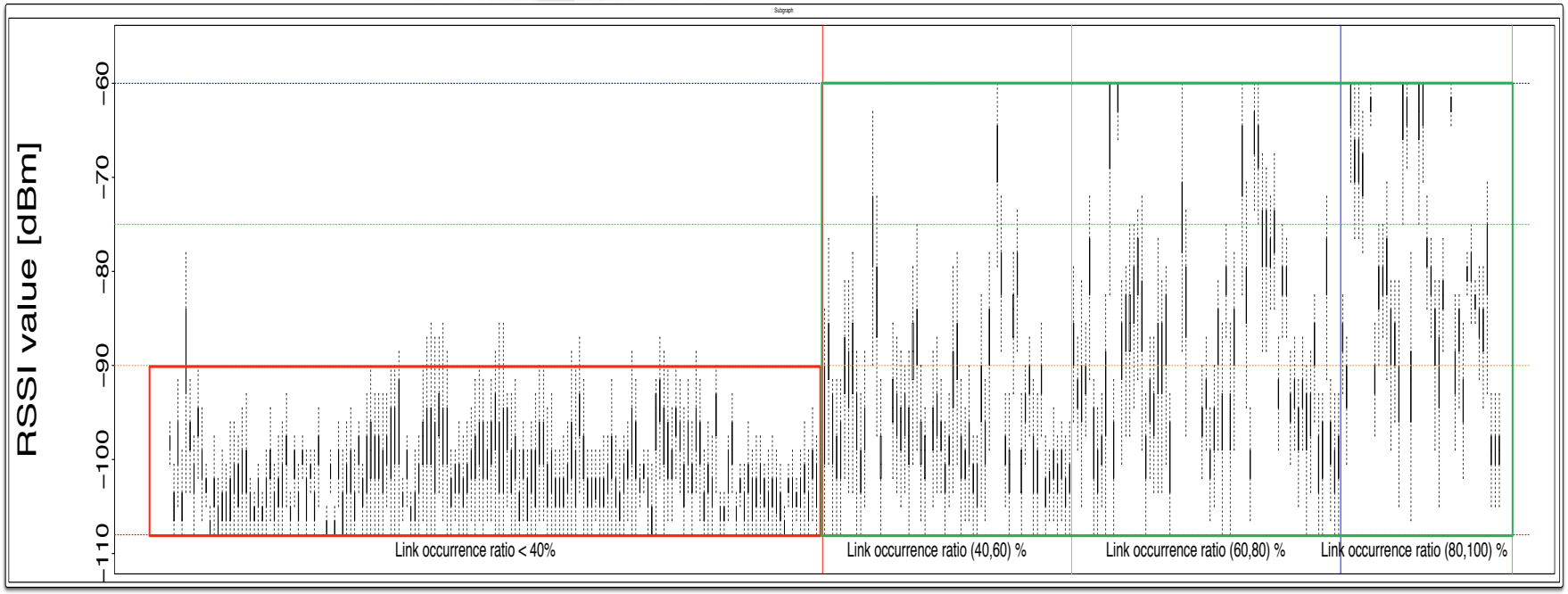


Link occurrence ratio

- ***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 %

RSSI vs Link occurrence ratio



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

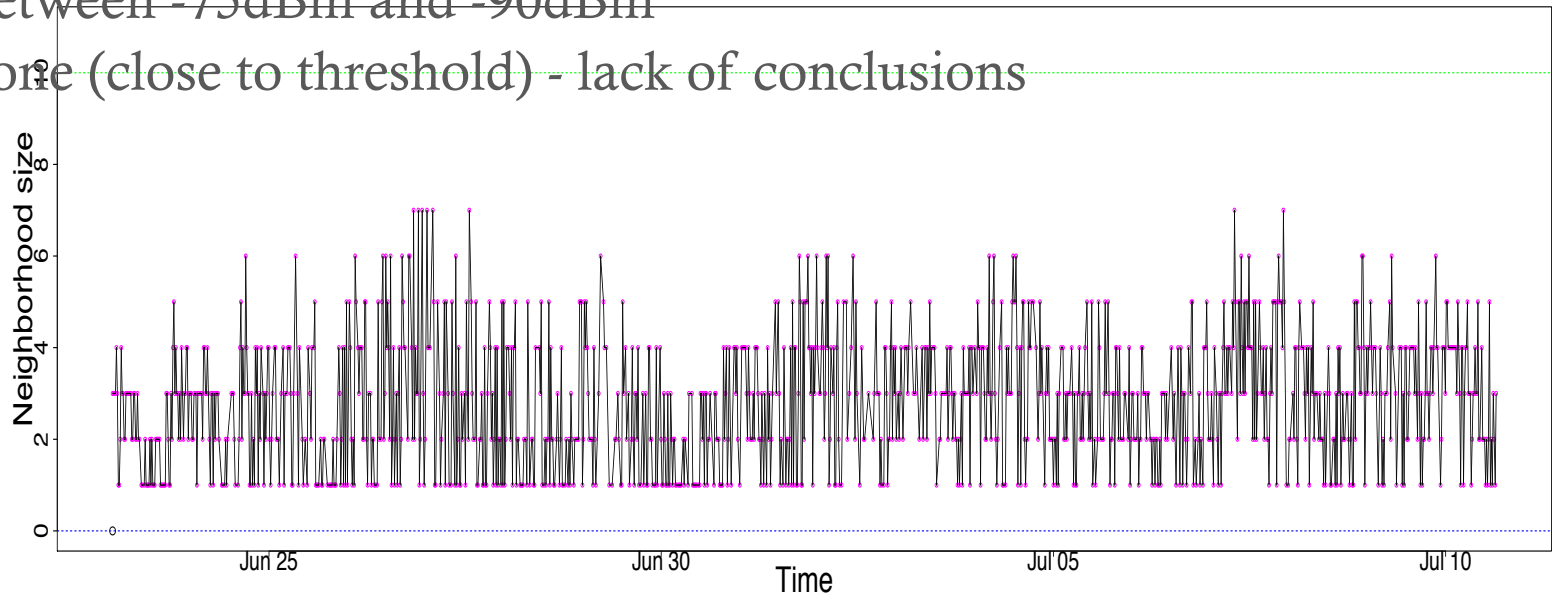
- Individual conclusions are not possible
- The largest RSSI values ~ the stable links.

Network dynamics

Neighborhood dynamics

Conclusions:

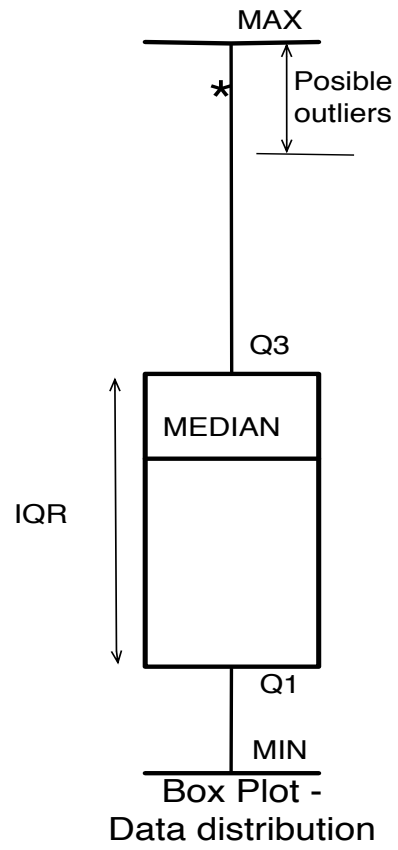
- High variations in neigh. tables =>
  USE reactive approach
- Stable neighbors:
  high RSSI (>-75dBm) and close distance (d < 0.2•Rmax)
  or
  RSSI between -75dBm and -90dBm
- Gray zone (close to threshold) - lack of conclusions



Filtering outliers

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

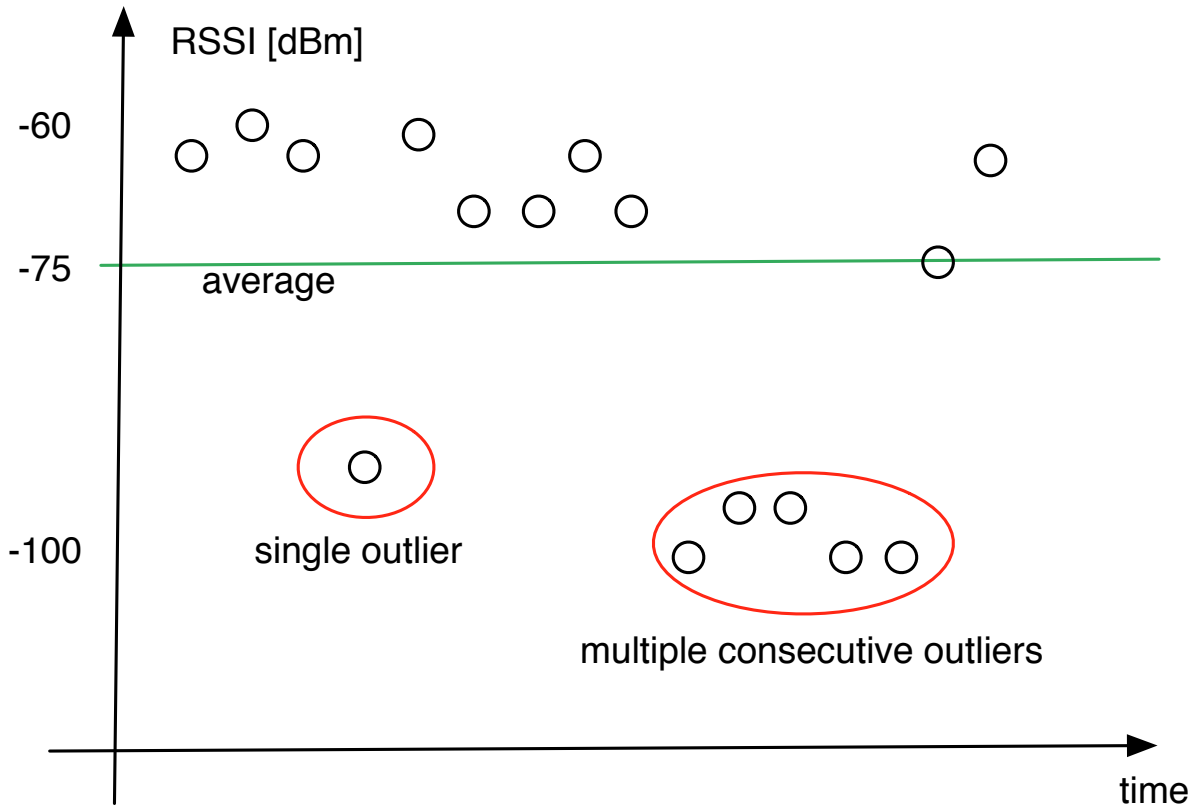
$$x < Q1 - 1.5 \cdot IQR \quad V \quad x > Q3 + 1.5 \cdot IQR$$



Box Plot - Data distribution

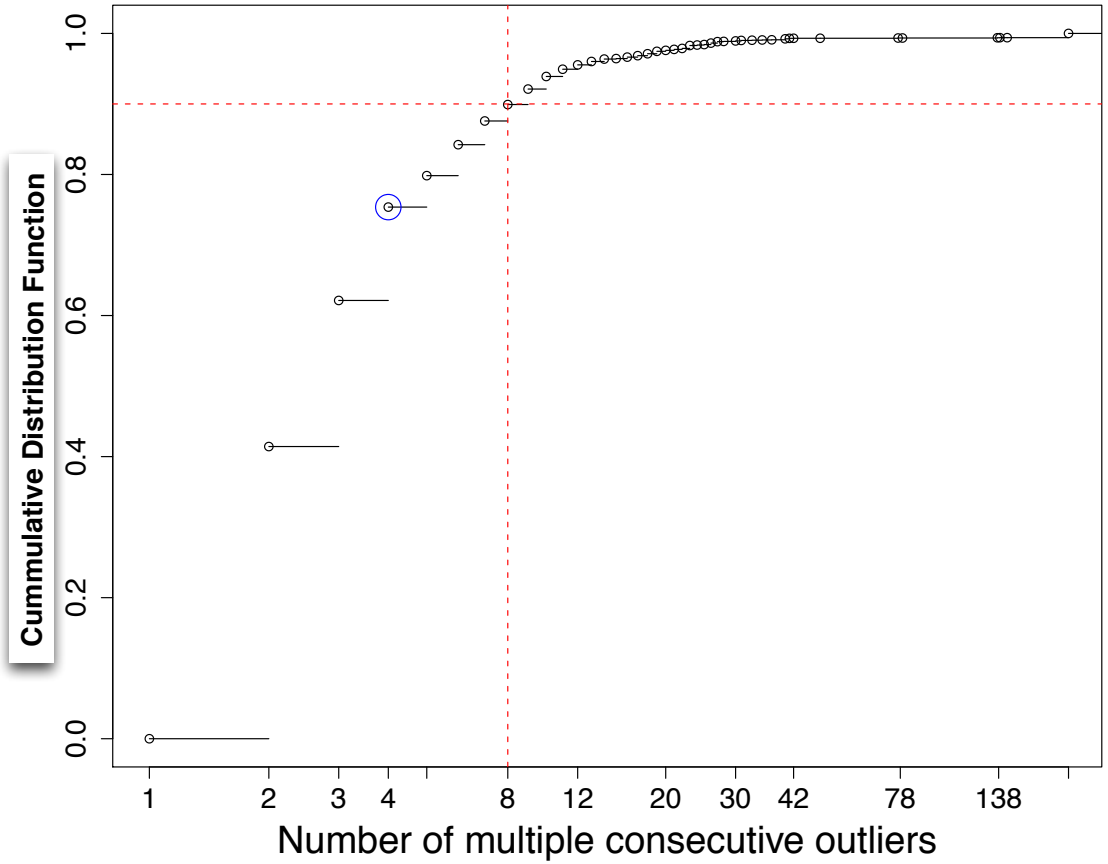
Link dynamics

- **Single outlier**: transitory effect
- **Multiple consecutive outliers (MCO)**: significant temporary change



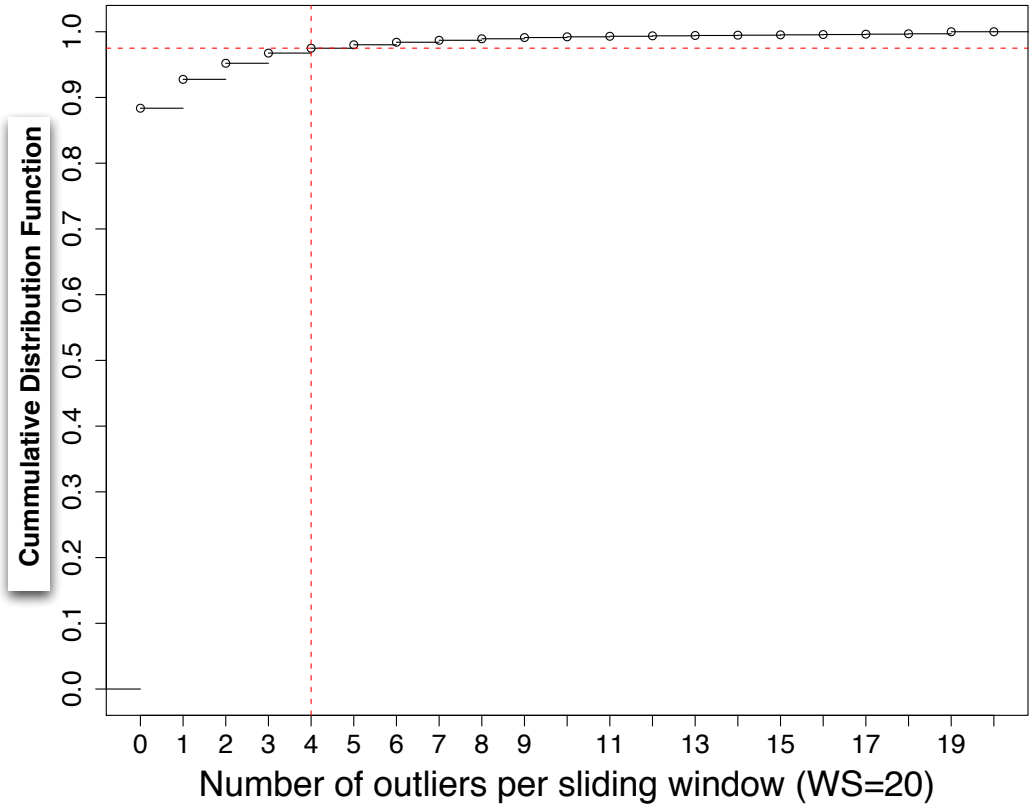
Link dynamics – global view

- **Global knowledge:** Total duration of experiment
- In 90% of the cases – 8 or less MCO



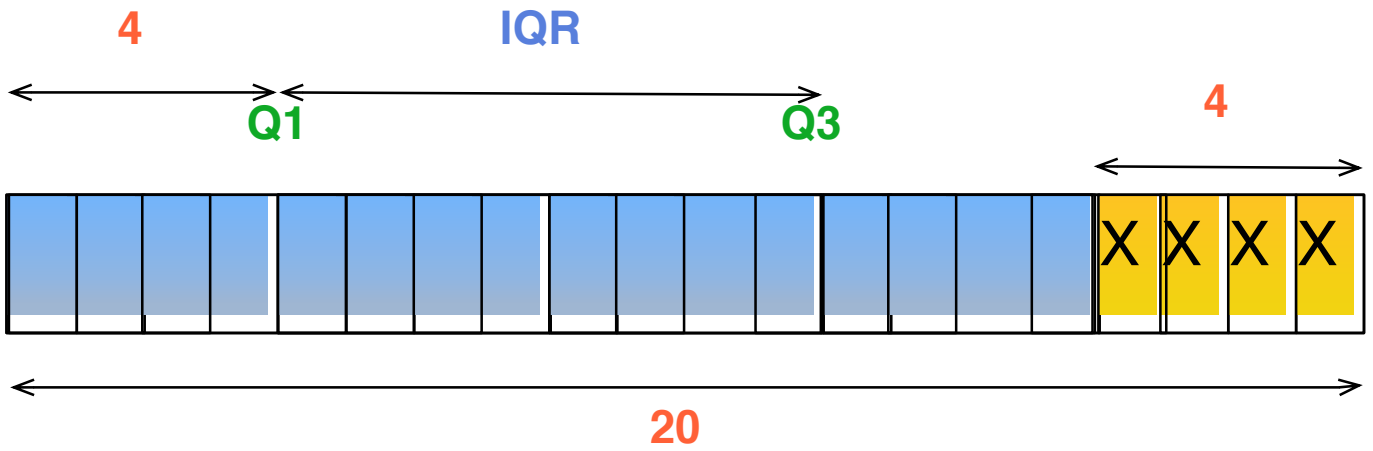
Link dynamics – local view

- **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

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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