A Quantitative Evaluation of the Simulation Accuracy of Wireless Sensor Networks

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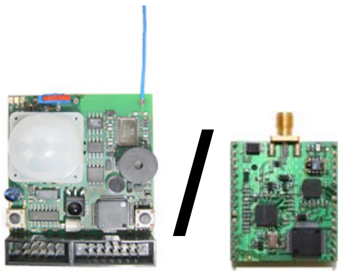
Outline

- Problem Statement: Simulation Accuracy
- Preliminaries: Network Metrics, Radio Propagation Models
- Experimental Setup
- Results / Discussion
- Conclusion / Future Work

Problem Statement: Background

- Simulation of ScatterWeb Applications on ns-2 [1]:



Application | Firmware | ScatterWeb Sensor Node

ScatterWeb C API

Application | Glue Code | Simulator

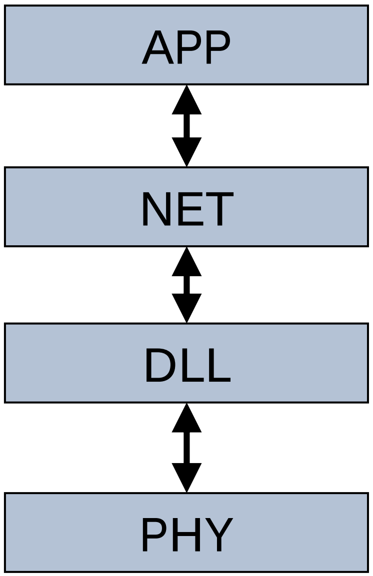
- Advantages:
  - Faster development cycle
  - Developer can concentrate on algorithmic issues first and deal with hardware-specific issues later
  - Algorithms can be evaluated in large networks under reproducible conditions

Problem Statement: Big Picture

- Goals:
  - Minimize differences between simulated and real sensor nodes from application perspective
  - Maximize simulation accuracy
- Required steps:
  1. Accurately implement firmware features in glue code
     - If possible, reuse existing components of simulator
  2. Establish correct parameters for simulator components
     - Easy for platform-specific parameters
     - Difficult for deployment-specific parameters, e.g. radio propagation model
  3. Quantify simulation accuracy
     - Choose appropriate metric
     - Compare data from field test with data from simulation

Preliminaries: WSN Network Metrics

- Metrics for different network layers as applicable in WSNs:



- Application QoS Parameters

- Packet Delivery Rate (PDR)
- Hop Count, Latency, Overhead Traffic

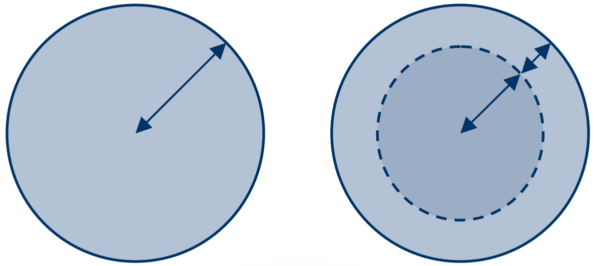
- Packet Loss Rate (PLR)
- Packet Collision Rate (PCR)

- Bit Error Rate (BER)
- Radio Signal Strength (RSS)

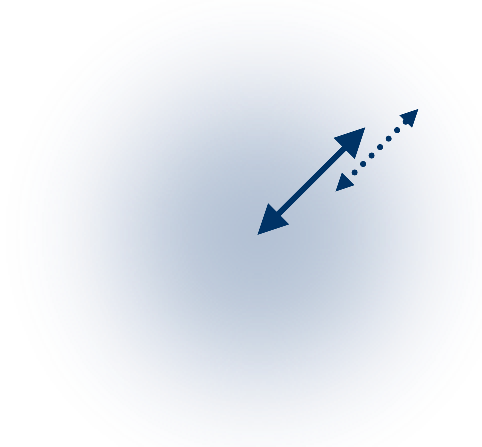
- Rationale:
  - Well supported as networking concept in virtually all simulation tools (bit errors, for instance, are not)
  - Avoid tying our results to any particular routing protocol

Available radio propagation models in ns-2:

- Free space / Two-ray ground reflection
  - Unit disc models
  - Do not model packet loss rate
  - ➢ Not applicable



- Shadowing
  - Probabilistic model
  - Does model packet loss rate
  - ➢ Applicable



Preliminaries: Shadowing Model

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$$\left[\frac{P_r(d)}{P_r(d_0)}\right]_{dB} = -10\beta\log\left(\frac{d}{d_0}\right) + X_{dB}$$

- $P_r(d)$ – Mean received power at distance d
- $P_r(d_0)$ – Reference power at distance d_0
- β – Path loss exponent
- X_{dB} – Gaussian random variable with zero mean and standard deviation σ_{dB} , called *shadowing deviation*

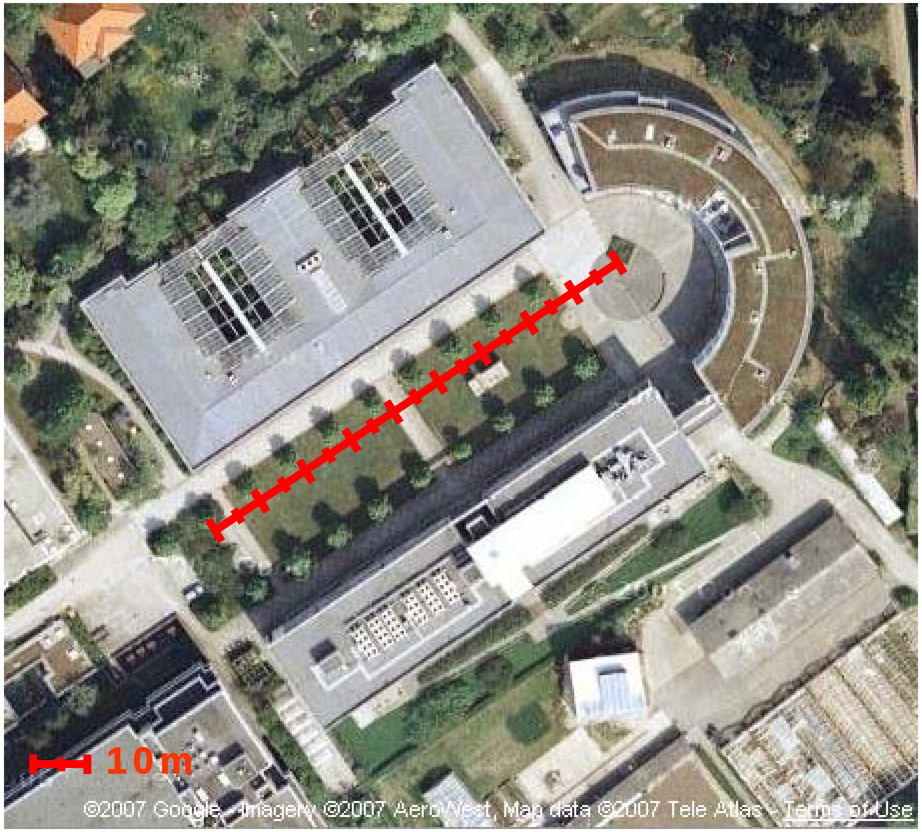
Typical values for path loss exponent and shadowing deviation [2]:

Environment		β
Outdoor	Free space	2
	Shadowed urban area	2.7 to 5
In building	Line-of-sight	1.6 to 1.8
	Obstructed	4 to 6

Environment	σ_{dB} (dB)
Outdoor	4 to 12
Office, hard partition	7
Office, soft partition	9.6
Factory, line-of-sight	3 to 6
Factory, obstructed	6.8

Experimental Setup: Field Test

- Two ScatterWeb ESB sensor nodes
  - Urban outdoor environment
  - 60 cm above ground
  - No obstructions in direct line of sight
- Distance between nodes
  - Range from 5 m to 90 m
  - Steps of 5 m
- Firmware API transmission power setting
  - Range from 0 and 100
  - Steps of 10
- Establish packet loss rate based on 20 128-byte packets

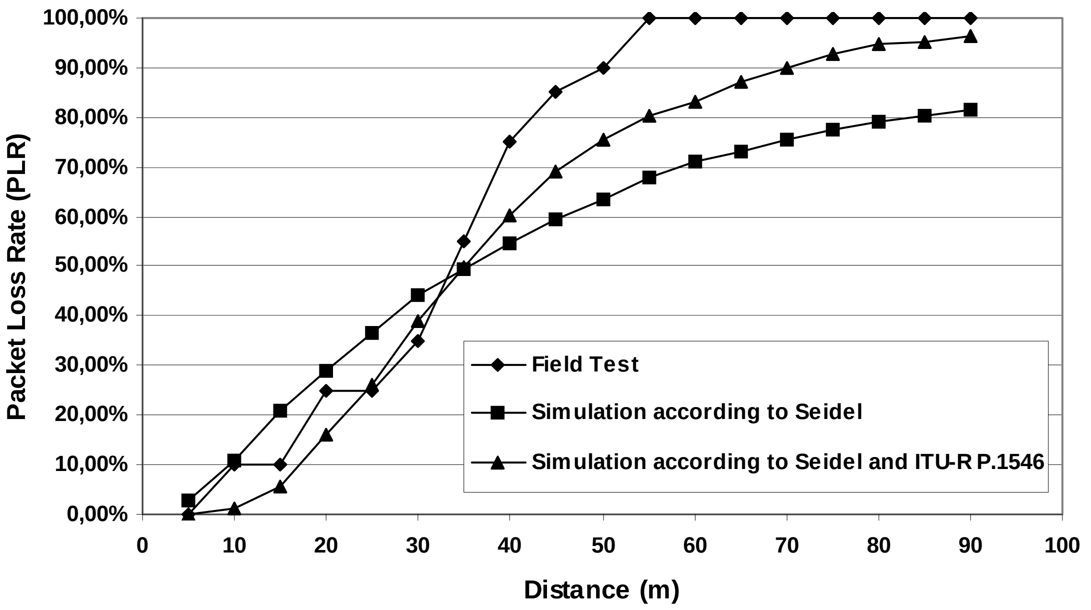


Experimental Setup: Simulation

- Detailed simulation of hardware / firmware features
  - Match firmware API setting to real transmission power
  - Support for per packet transmission power in ns-2

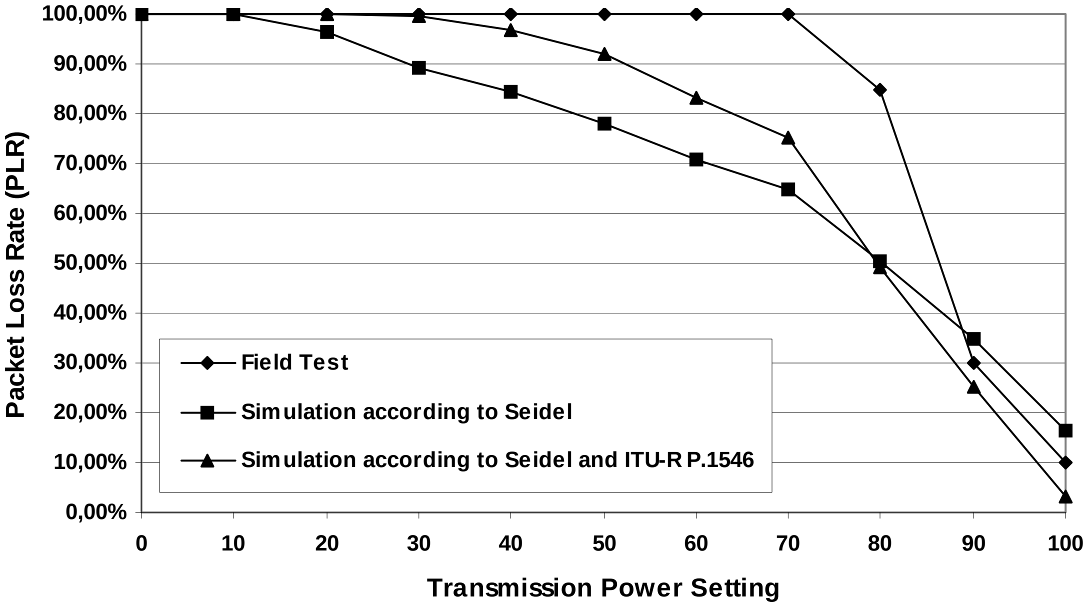
- Recreate field test in simulator
  - Few good recommendations for radio propagation parameters in literature
  - Generally focus on larger communication ranges (> 1 km) and different frequencies (IEEE 802.11, GSM)
  - Most suitable parameters:
    - Seidel [3]: $\beta = 2.7$; $\sigma_{dB} = 11.8$ dB for 900 MHz
    - ITU-R P.1546 [4]: $\sigma_{dB} = 9.5$ dB for 900 MHz
  - ➢ Simulations with combinations of both

Results: Packet Loss Rate (1)



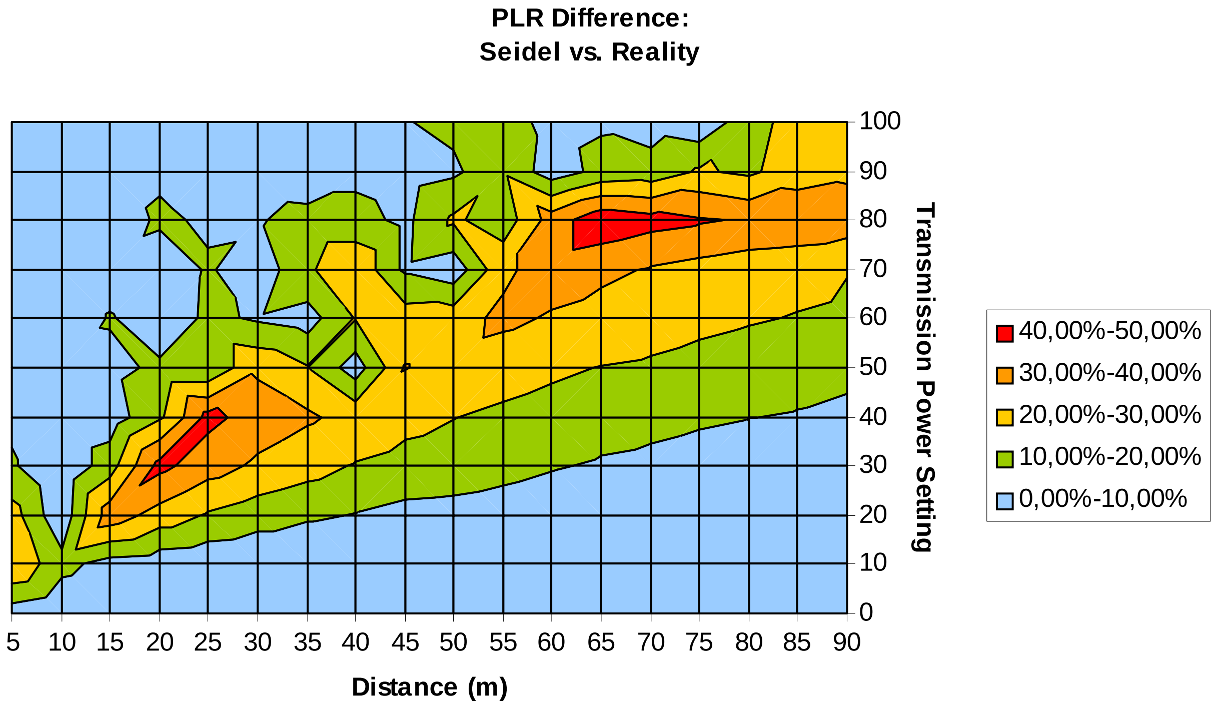
Packet loss rate against distance between nodes with transmission power setting fixed at 60

Results: Packet Loss Rate (2)



Packet loss rate against transmission power setting with distance between nodes fixed at 60 m

Results: PLR Differences (1)



Packet loss rate differences between simulation and reality with parameters according to Seidel

Results: PLR Differences (2)

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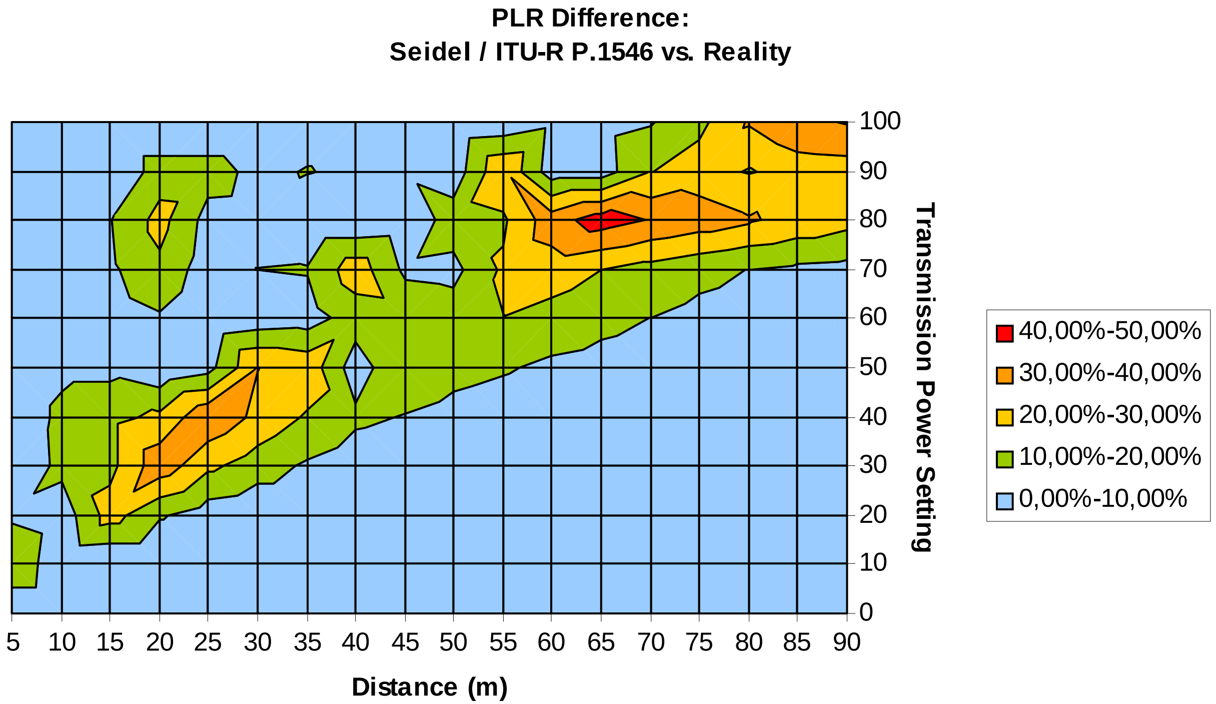

Packet loss rate differences between simulation and reality with parameters according to Seidel and ITU-R P.1546

Conclusion

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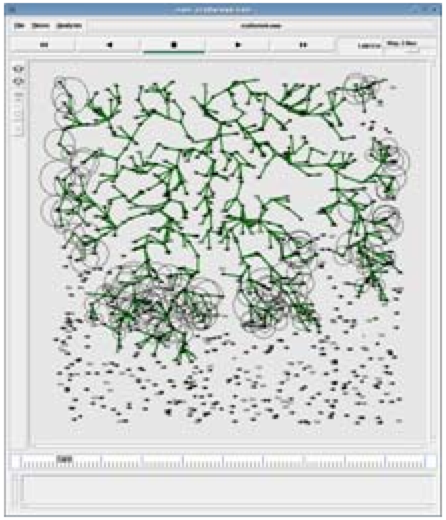
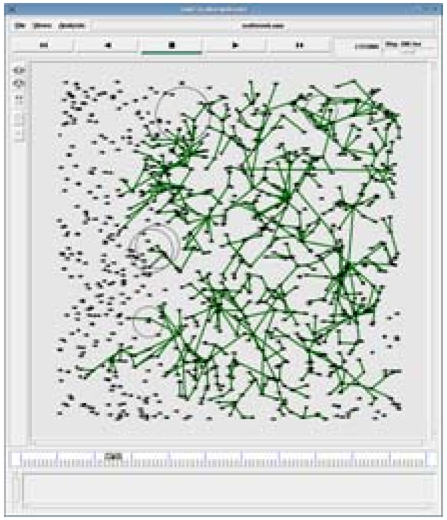
- Quantitative evaluation of simulation accuracy with regard to packet loss rate
- Comparison of data from field test against carefully configured simulation
- Average difference between simulation and reality is 12.3% or 8.2%
  - Depends on parameters of radio propagation model

➢ Results allow to judge credibility of future simulations for similar deployments

Future Work

- Similar experiments for other metrics
- Analyze how simulation inaccuracies interact over different network layers

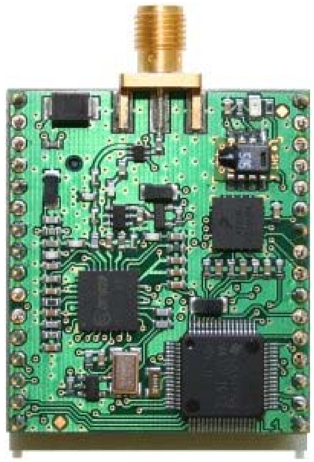


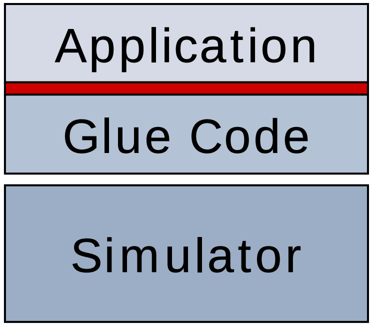


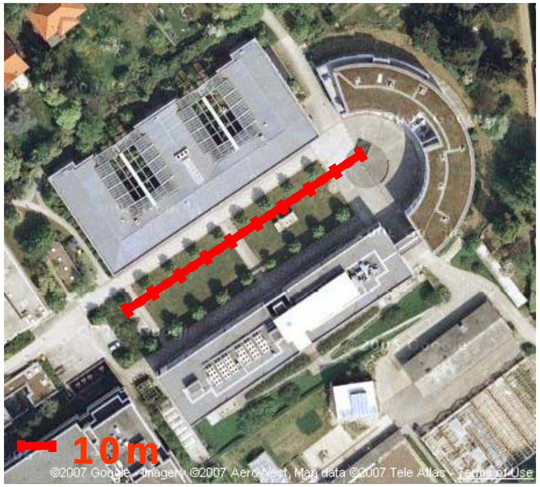
- Consider indoor scenarios using ray-tracing-based radio propagation models [5, 6]

Thank you for your time!

Any questions?







More at:
http://www.inf.fu-berlin.de/inst/ag-tech/scatterweb_net/software/ns2.html

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