An Empirical Evaluation of the Received Signal Strength Indicator for fixed outdoor 802.11 links

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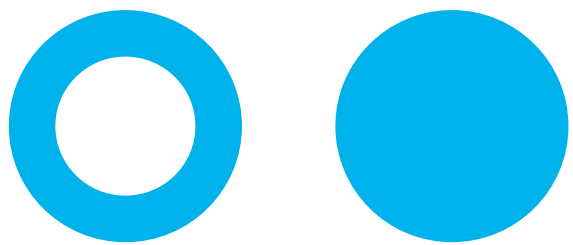

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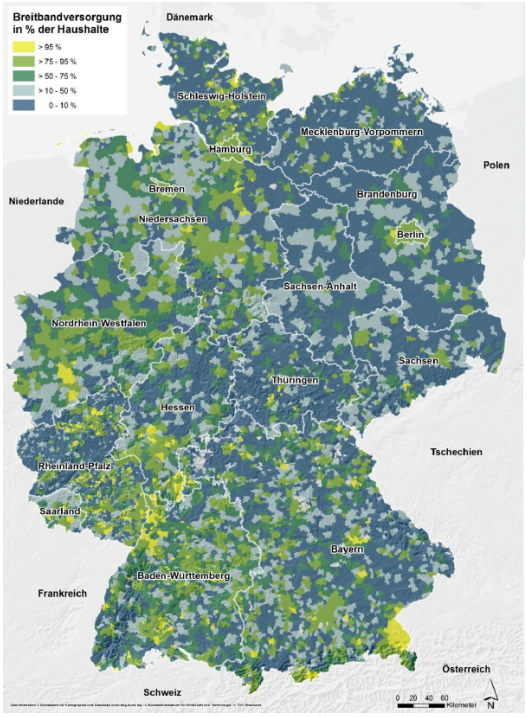
Introduction and Motivation

- Rural areas often lack (fast) connectivity
- WiFi long-distance mesh networks
- Last year: Optimization of the MAC [1]
- Received Signal Strength Indicator (RSSI)
  - Indicate optimum parameters
  - Path loss model verification [2] [3]
  - Indicate *interferences*

-> *Dynamic frequency allocation*



Broadband $\geq$ 50 Mbps (2014) [4]

Research questions:

Variation of the RSSI in a stable short-term environment.

Samples needed to determine "real" RSSI.

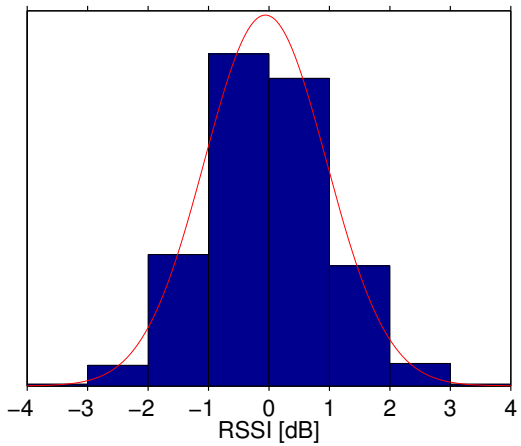
Distribution function of the RSSI.

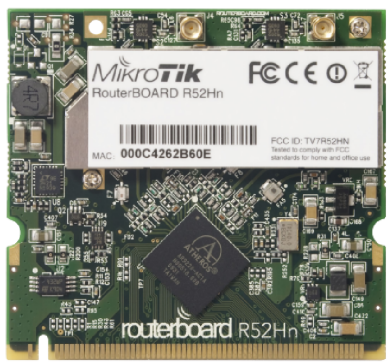
The impact of the **production series**.

Related Work

- [5] RSSI is predictable and Gaussian
- [6] RSSI is non-predictable and non-Gaussian
- [7] wrong modeling of RSSI; wrong simulations
- [8] similar conducted experiments:
  - Variation of the measured RSSI: 15.5 *dB*
  - Mean RSSI varies greatly during one experiment
  - non-Gaussian
- [9] RSSI distributions are left-skewed
  - Depended on line-of-sight and signal power
- [10] smartphone based location services:
  - Variation of the measured RSSI: 15.5 *dB*
  - Distribution: positive kurtosis and left-skewed

-> All experiments are conducted indoor.





Methodology - RSSI Measuring

We used two different methods to obtain the RSSI:

Libpcap

- Currently best practice [11][9][10]
- Values reported from the driver
- Per 802.11 packet
- Integer accuracy (-74,73)
- Radiotap-Field: Antenna Signal
- Filtering to 802.11 data packets

Spectral snapshots FTT

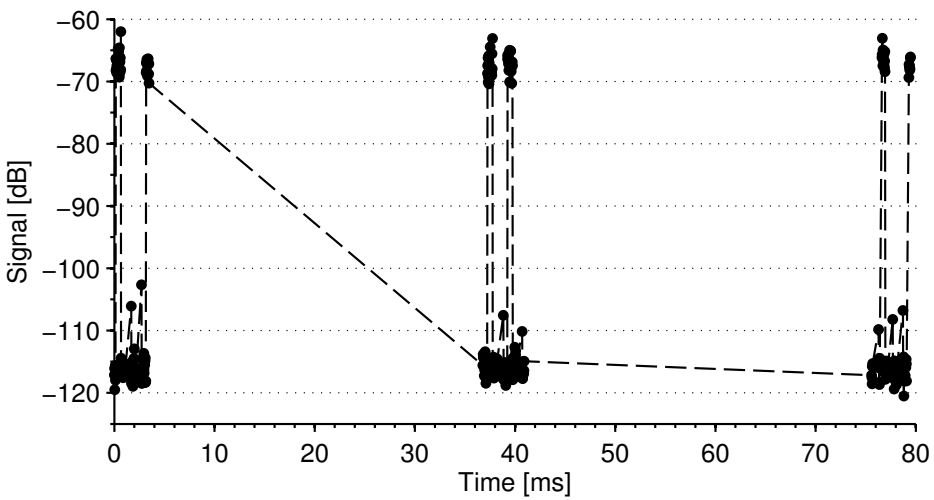
- Newly evaluated
- I/Q data from the NIC
- Per OFDM-subcarrier
- Increased accuracy
- Additional processing needed
- Qualcomm/Atheros NICs [12]

Methodology - RSSI Measuring - Spectral snapshots FTT

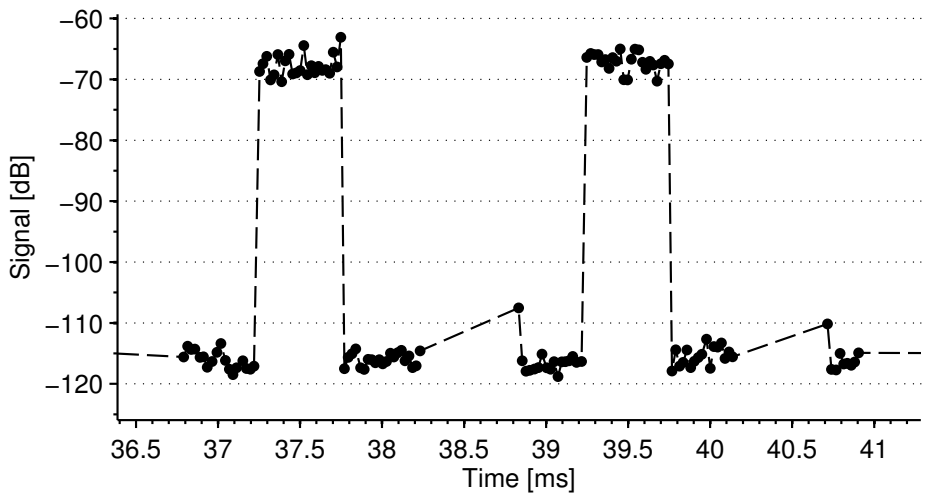
- Additional software is needed to interpret the binary data [13]
- Userspace trigger -> 56 * I/Q data from WiFi NIC: $z_i = I_i + Q_i$
- Repeated every 3-4 μs for a 200 spectral scans

$$RSSI_i = N + SNR - 10 * log_{10}(\sum_{i=1}^{56} z_i^2) + 10 * log_{10}(z_i^2)$$ RSSI per subcarrier

$$RSSI = 10 * log_{10}(\sum_{i=1}^{56} 10^{\frac{RSSI_i}{10}})$$ Overall RSSI



Data capturing: 3 scans.

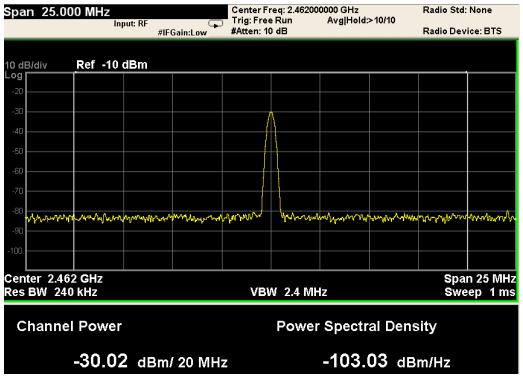


Zoom into a single spectrum scan.

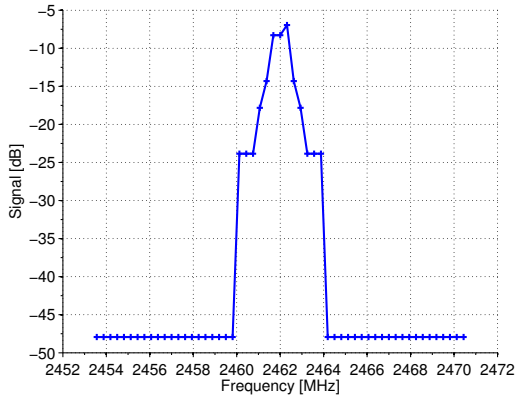
Comparability of WiFi NIC spectrum scanner

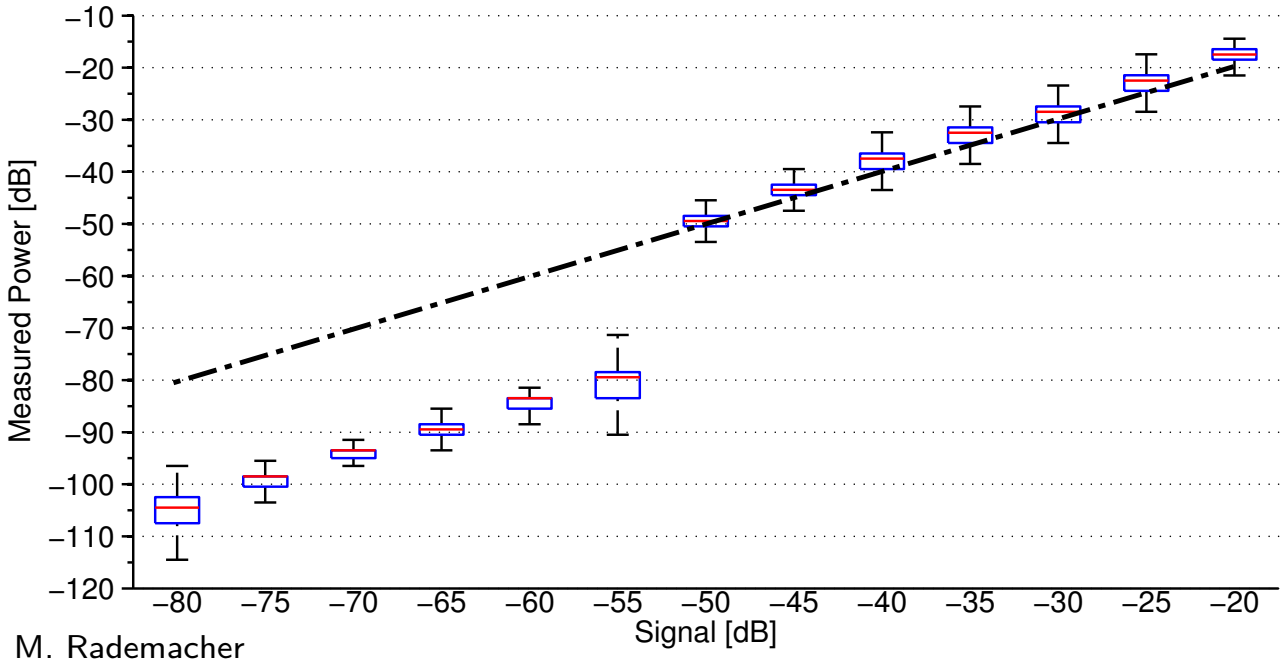
- Artificial signal at 2.4 GHz simultaneously to

Industrial spectrum analyzer



Atheros WiFi NIC spectrum scan





Spectrum scan (boxes)
vs
spectrum analyzer (line)

Methodology - Setting up the experiments

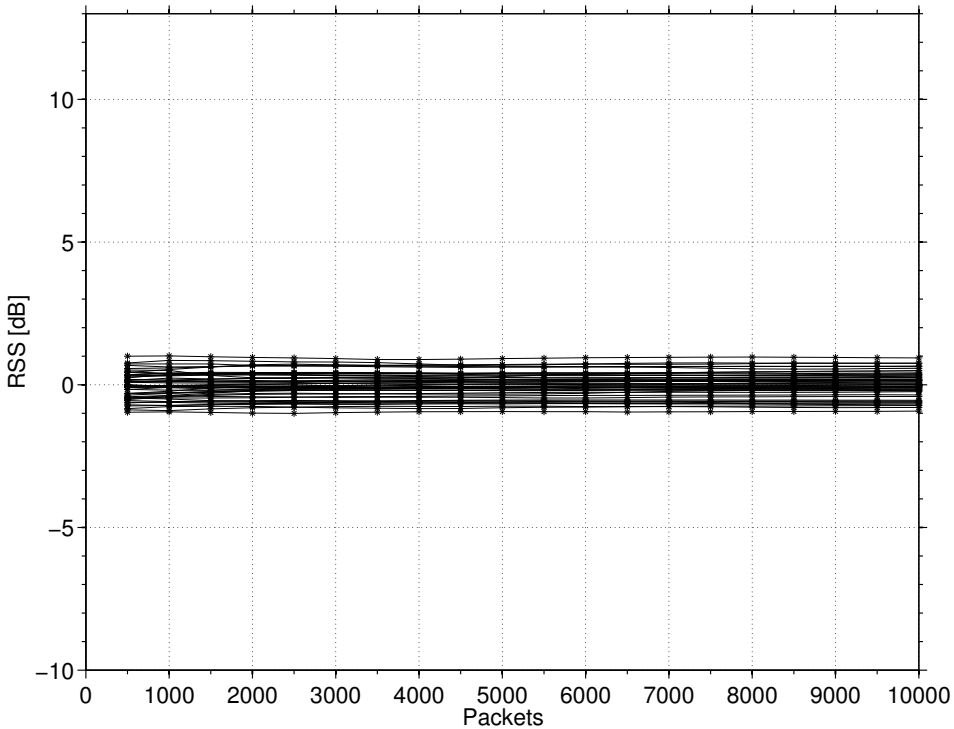
- First experiments indoor
  - -> Multipath-propagation
- Switch to outdoor environment
  - Line-of-sight
  - No reflections or interferences
- 50 measurements per card
- 3 different cards
- Transmitter -> Receiver (RSSI)

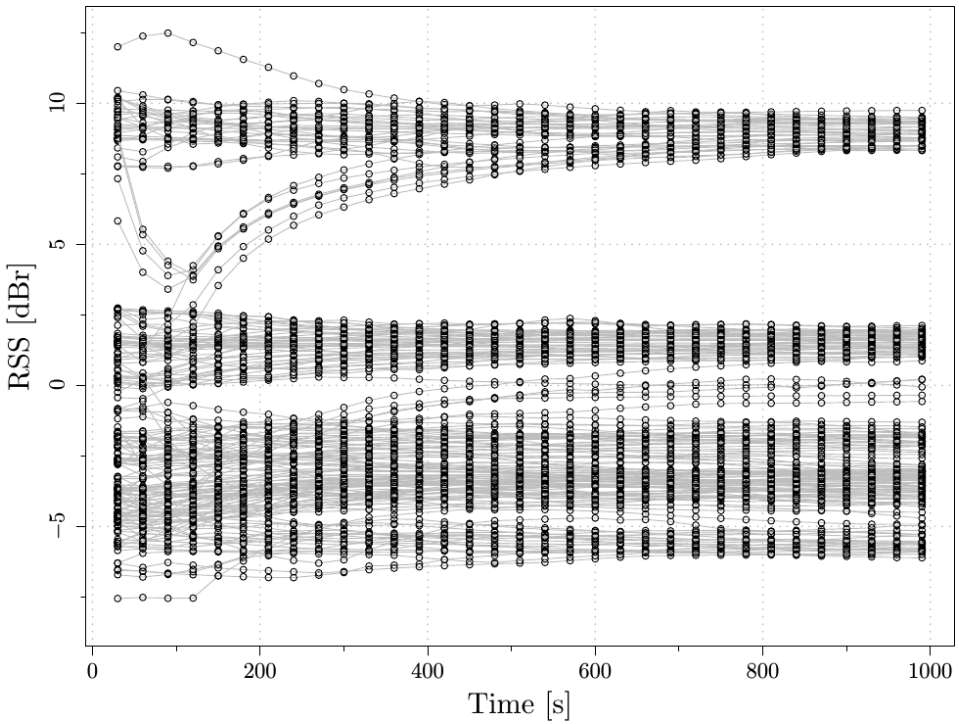
Hardware and Software used

System Board	Alix 3D2
WiFi Card	R52HN (AR9220)
Linux Kernel Rev	3.16.7
Libpcap and tshark	1.3.0 and 1.8.2
mgen	v5.02, UDP
traffic	500 PPS, 1450 Byte
802.11	5240 MHz, 6 Mbps

Variation of the RSSI in a stable short-term environment

- Sample means in reference to the overall mean (50 measurements).
- Normalized to 0 dB for comparison with [8]





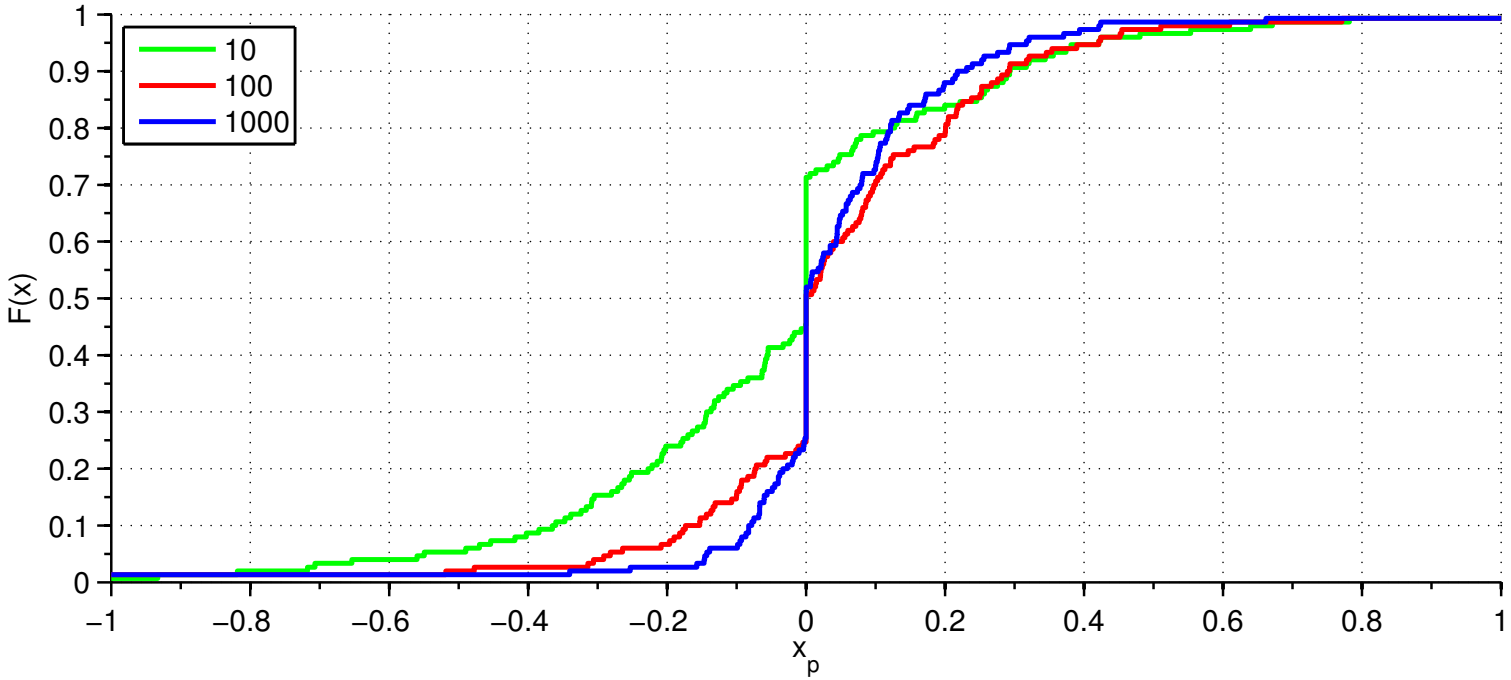
Our Results (libpcap) ≈ 1 *dB*

Results in [8] ≈ 15 *dB*

- Similar results based on spectrum scan feature < 1 *dB*

Samples needed to determine “real” RSSI.

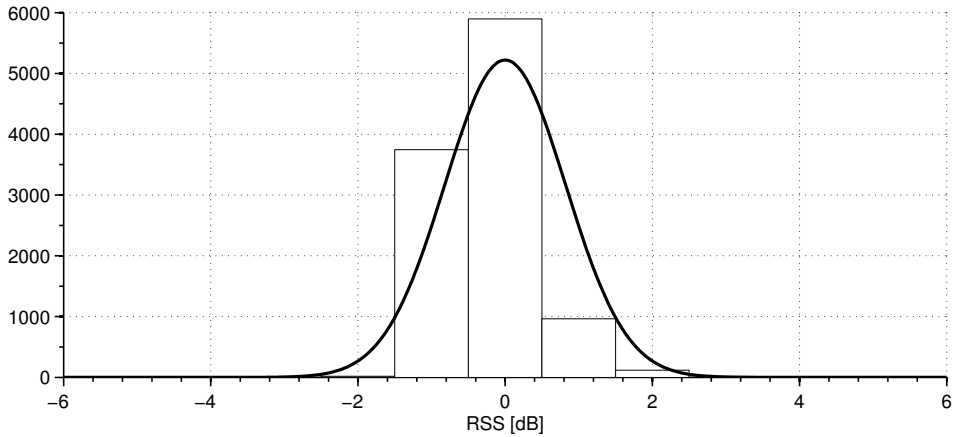
- Deviation of the mean after a certain amount of packets.
- ECDF using 150 independent measurements



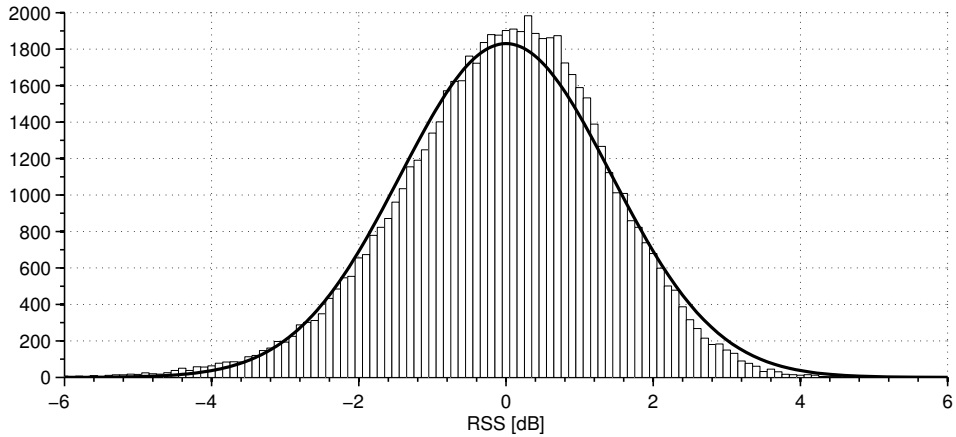
-> Less packets needed / less deviation compared to [8].

-> After 1000 packets. Mean does not change more than 0.5 dB.

Distribution function of the RSSI - Histograms



Based on libpcap



Based on spectral scan

- Spectral scan feature provides greater accuracy.
- Based on spectral scan check for normality using:
  - Kolmogorov-Smirnov test [14]
  - Lilliefors test [15]
  - Jarque-Bera test [16]
- At a significance level of 5%, for all experiments, all tests reject the null hypothesis that "the data origins from a normal distribution"
- Negative skewness and positive kurtosis for all experiments

The impact of the **production series**

Test	Cards	RSSI Std		Kurtosis	Skewness
		pcap	Sscan	Sscan mean$\pm$Std	
1	$1 \mapsto 2$	0.43 dB	0.34 dB	3.42 ± 1.14	-0.64 ± 0.09
2	$2 \mapsto 3$	0.40 dB	0.34 dB	1.84 ± 0.58	-0.45 ± 0.06
3	$3 \mapsto 2$	0.39 dB	0.33 dB	1.68 ± 0.58	-0.43 ± 0.06

- Comparison of different WiFi cards:
- Low RSSI standard deviation occurs in a predictable way.
- A left-skewness and kurtosis occurs in a predictable way.
- This verifies the trend reported by other researchers [9]
- Other distributions may occur from indoor propagation effects?

Conclusion and Summary

- Analysis of the RSSI for **fixed** 802.11 outdoor point-to-point links
- First analysis **without additional propagation** effects
- A new **methodology** for obtaining RSSI values based on the **spectrum scan** feature of recent Atheros/Qualcom WiFi card
- We have shown a much **smaller variation** of the RSSI mean among independent transmissions compared to [8, 9]
- We measured a **constant skewness and kurtosis** for the distribution
- The RSSI value can not be described by a normal distribution

Future work

- Study the influence of different parameters
  - Distance, transmission power
- Evaluate propagation models for long-distance 802.11 based links
- Build a dynamic interference classifier
  - Let spectrum scan run in background
  - Aggregate data and report changes

-> Dynamic Frequency Allocation

Thank you very much!

Are there any questions?

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