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SCALE: A Tool for Connectivity Assessment in Lossy Environments

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SCALE: A tool for Connectivity Assessment in Lossy Environments

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Goal: understand **qualitatively** and **quantitatively** the factors affecting low-power radio propagation

Why is this important?

- Reality guides algorithm development and protocol parameter tuning
- Data for better propagation models used in simulations

Design Parameter	Data Collected	Utility
Physical density	Delivery rate vs. distance	Expected mean topological density
		Expected standard deviation in topological density
Algorithmic selection	Delivery rate vs. environment type and distance	Expected performance of in-network processing, e.g. opportunistic (geographical) data aggregation
		Expected performance of spatial correlation, e.g. geographical and topological routing
Protocol selection	Link asymmetry vs. distance	Expected performance of routing mechanisms that assume bidirectional links
Protocol parameters (time constants)	Delivery rate vs. time	Find reasonable routing and application soft state refresh time; find neighbor discovery probe period as a function of the stddev.
	Link asymmetry vs. delivery rate	Find neighbor discovery period as a function of mean and stddev.
Packet size selection	Delivery rate vs. packet size	Find optimal packet size to maximize efficiency ⁹

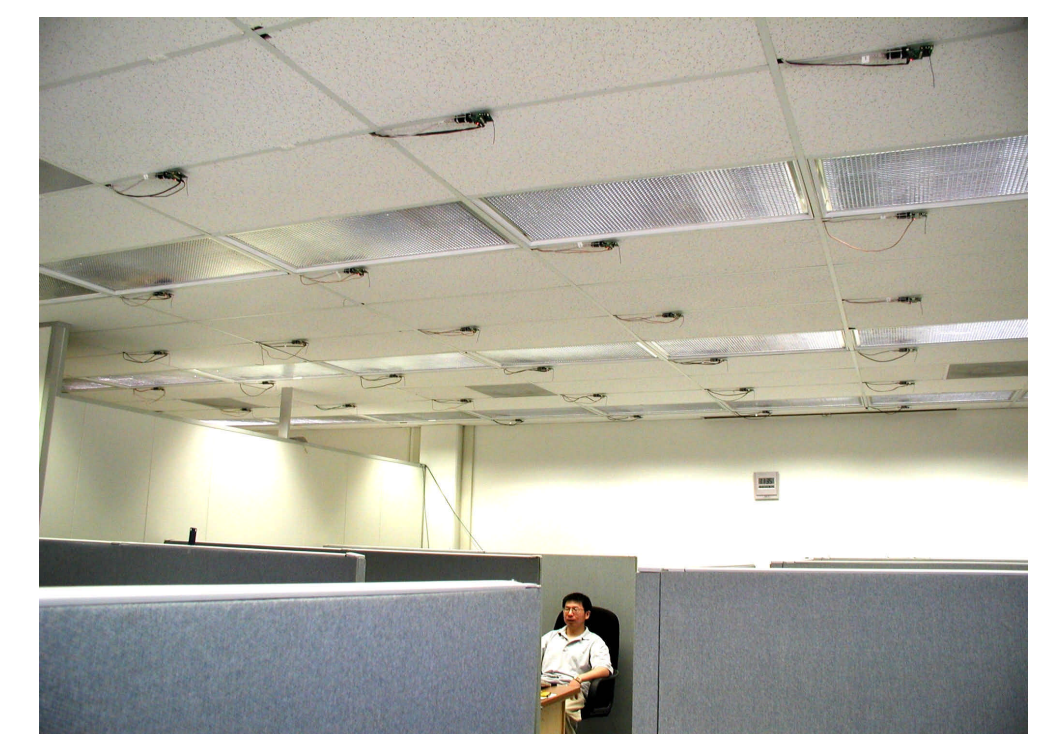
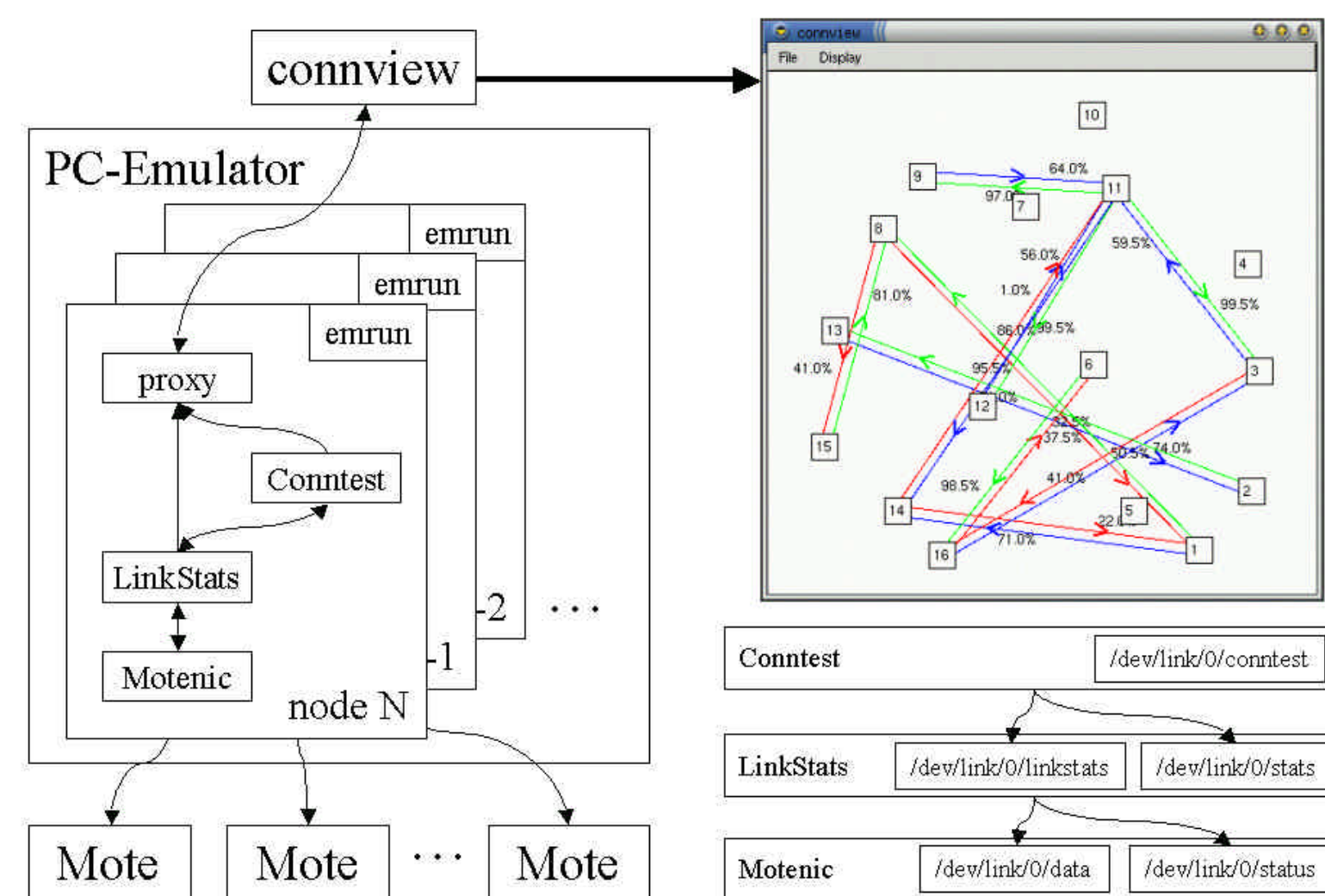
Preliminary Results using SCALE

- Great **variability** over distance (50 to 80% of radio range)
 - Reception rate is not normally distributed around the mean and std. dev.
 - Real communication channel is **not isotropic**
- Found 5 to 30% of **asymmetric** links
 - Not correlated with distance or transmission power
 - Primary cause: differences in **hardware calibration** (rx sensitivity, energy levels)
- Time variability is correlated with **mean reception rate** and not correlated with distance from the transmitter

One tool fits all: use the **same** radio device in the **same** target environment intended for deployment

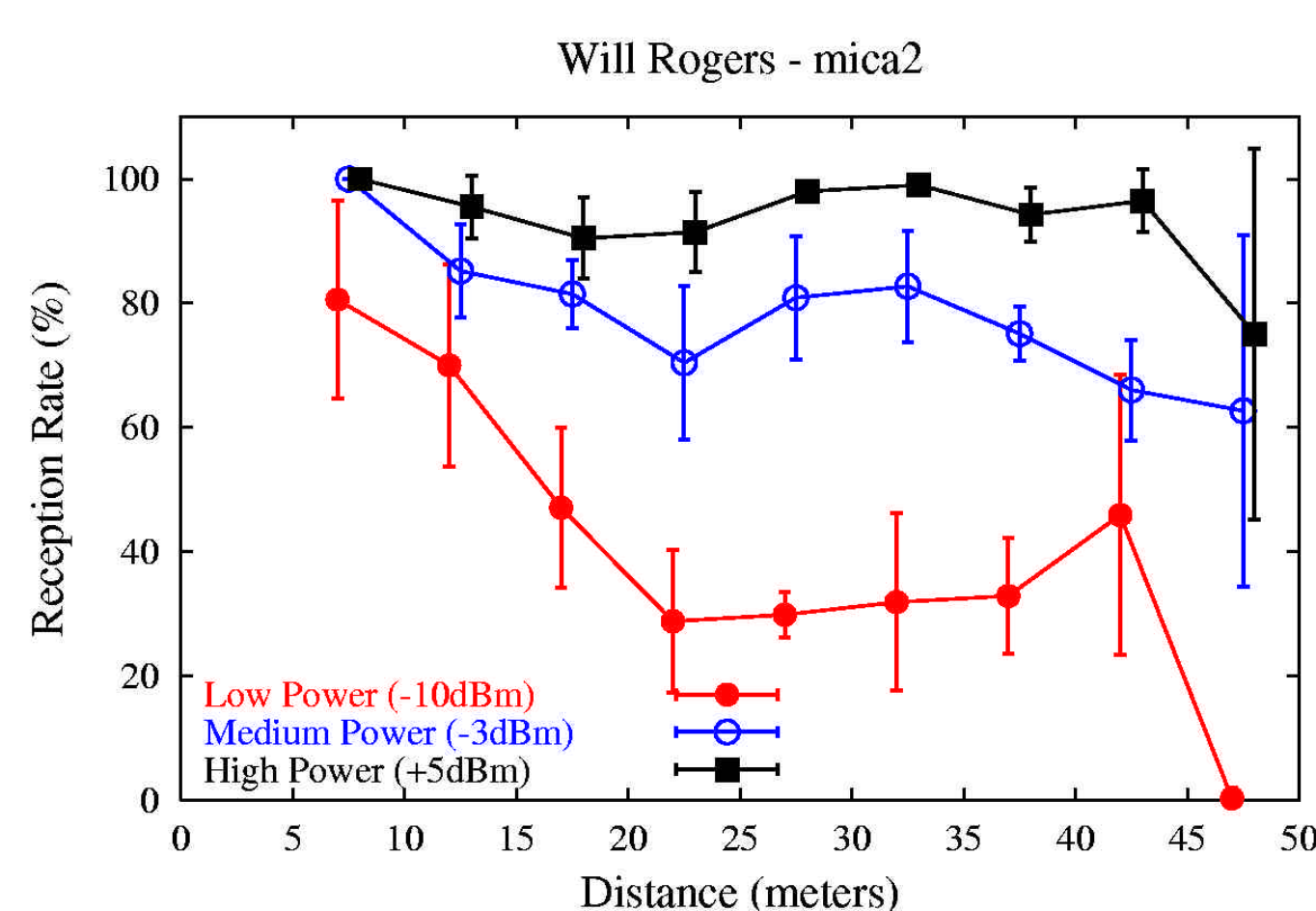
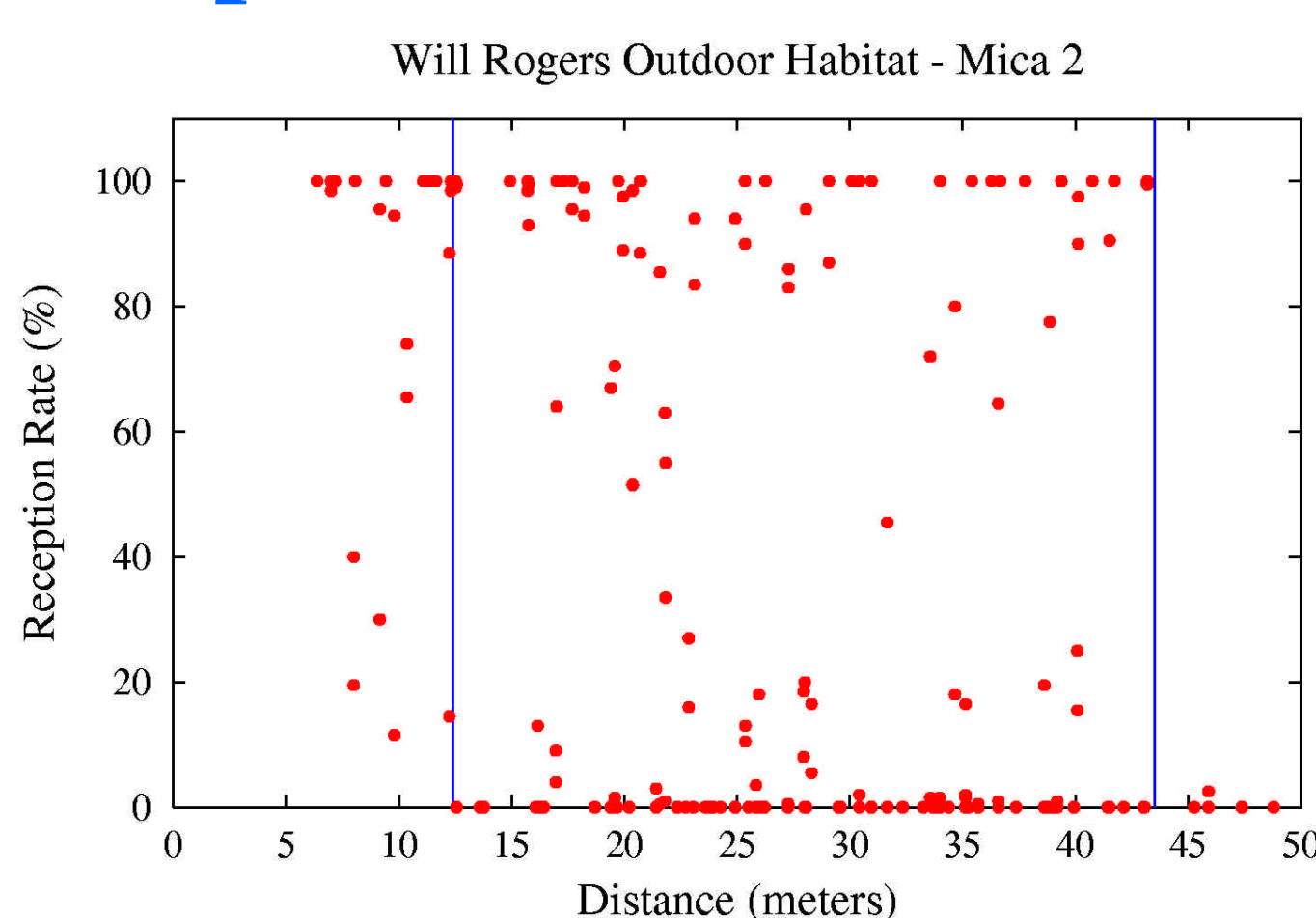


- Modular** software design that leverages on EmStar features (job control, debugging, etc.)
- Runs in centralized or fully distributed way (no code change)
- Visualization tool** to check the status in real time and post-experiment analysis
- Fully **configurable**: # and size of packets, data rate, TX gain
- Test 3 different environments:
 - Outdoor Habitat: Will Rogers Park; Outdoor Urban: Boelter Hall Court Yard; Indoor: LECS Lab Ceiling.
- Use 2 different hardware platforms:
 - Mica 1: RFM 916MHz, ASK, 13.3kbps; Mica 2: Chipcon 433MHz, FSK, 19.2kbps

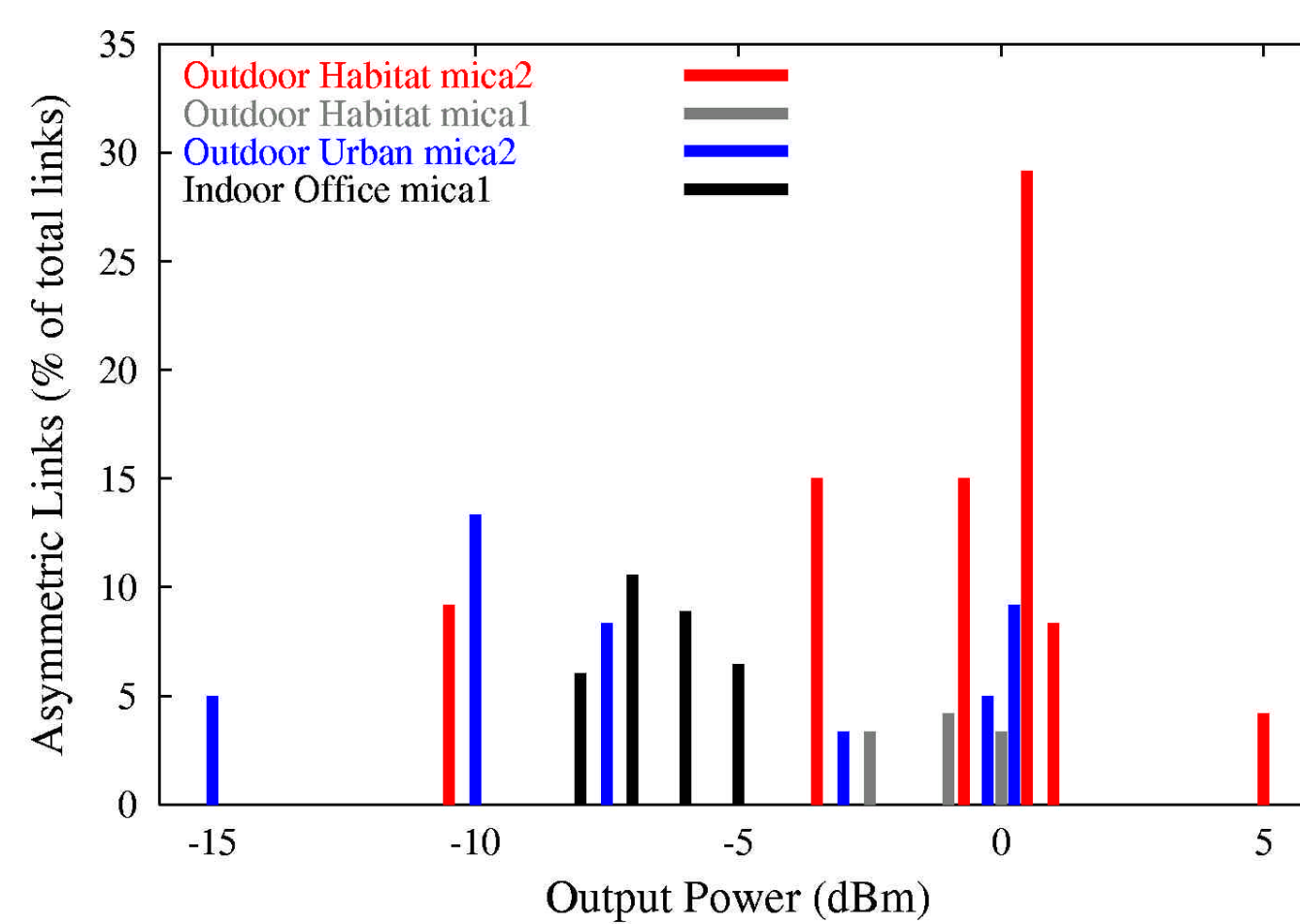


Experimental Results: channel **variability**, the norm for low-power radios

Spatial Characteristics

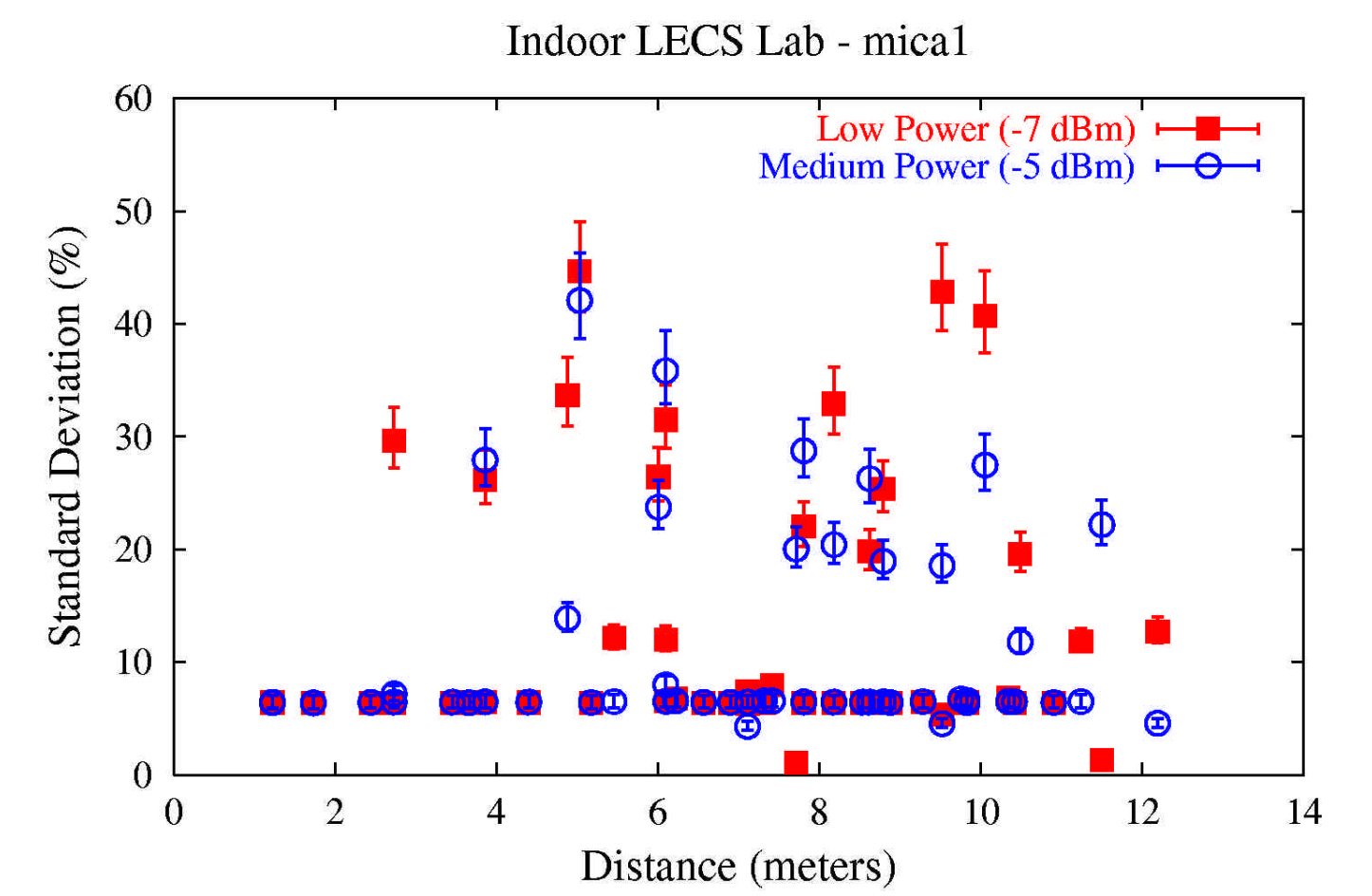
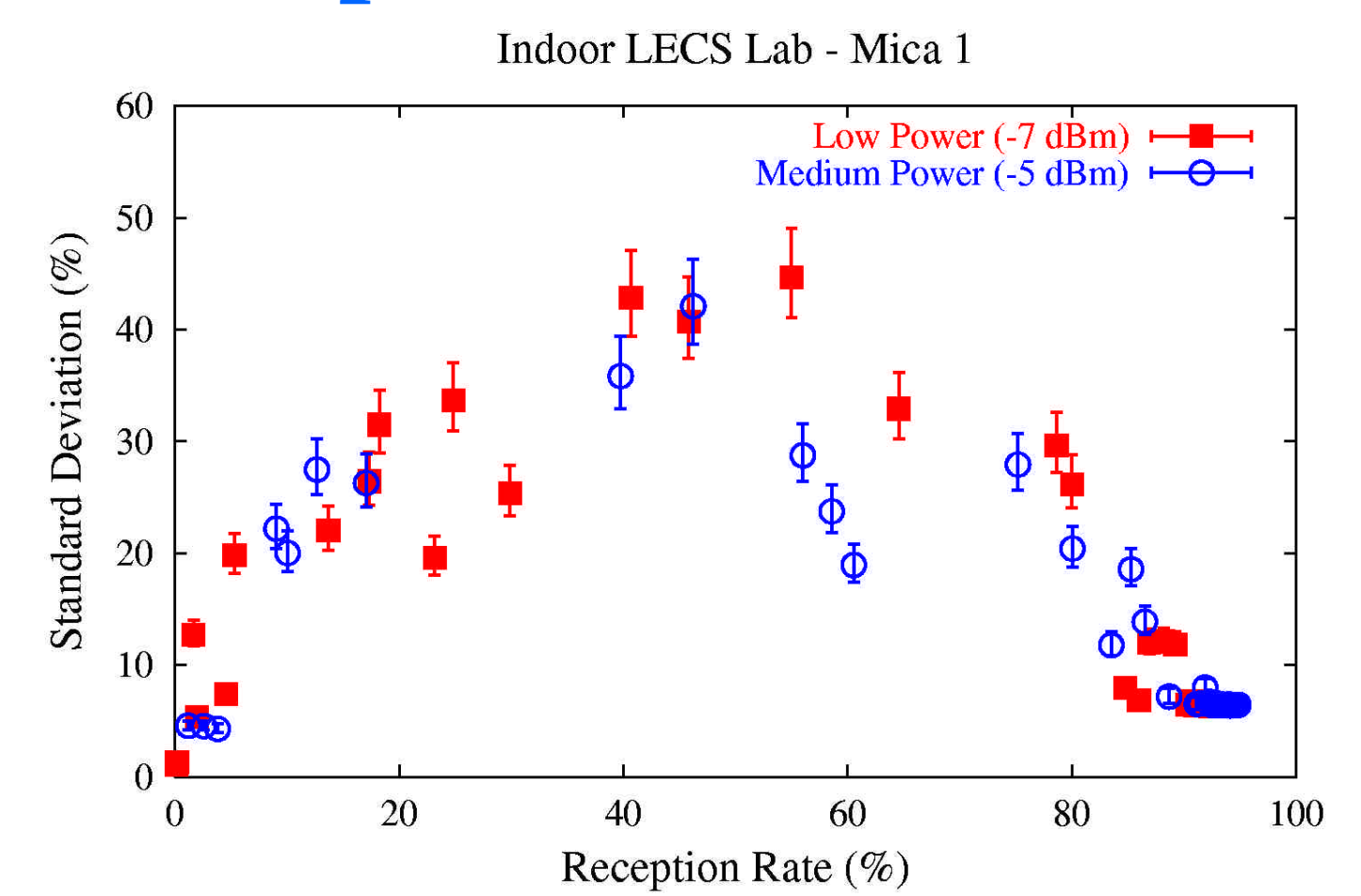


Asymmetric Links



Node Type	Location Type	Asymmetric link-pairs before swapping	Inverted link-pairs after swapping
Mica 2	Outdoor Urban	11	10
Mica 2	Indoor Office	10	9
Mica 1	Indoor Office	24	22

Temporal Characteristics



- Low** degree of correlation between distance and reception probability; lack of monotonicity and isotropy
- The region of highly variable reception rates is **50% or more** of the radio range, and it is **not** confined to the **limit** of the radio range

- No** simple **correlation** between asymmetric links and distance or TX output power
- When swapping the asymmetric links node pairs, the asymmetric links were **inverted** (91.1% ± 8.32)
- Link asymmetries are primarily caused by differences in **hardware calibration**.

- Links with **high** and **low** mean reception rate tend to be **stable** over time
- Links with **medium** reception rate tend to be highly **variable** over time
- Time variability is **not** correlated with distance from the transmitter