SCALE: A tool for Simple Connectivity Assessment in Lossy Environments

Presented By

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Wireless Radio Communication

- Enables sensor nodes to perform significant local coordination, distributed signal processing, and network self-configuration to achieve scalable, robust and long-lived networks.

Motivation

- Under harsh conditions, wireless communication is unpredictable and varies drastically with small spatial changes and on different time scales.
- Real communication channels are very difficult to model for the wide range of target environments and the different type of radios, frequencies, and modulation schemes in use.

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- Given the variability of the communication channel, and the difficulty to model it accurately, it is essential to get quantitative data that may allow us to better understand the channel characteristics in the target deployment area.

SCALE

- Measurement tool to study wireless communication channels with low power radios in new environments.
- Communication metric from the application point of view: packet delivery.
- Enables collection of packet delivery statistics using the *same* specific hardware platform and in the *same* environment intended for deployment.

Characteristics of SCALE

- The data gathered by *SCALE* may allow protocol developers and engineers to better estimate the appropriate density, system parameter tuning constants, and expected performance of protocols and algorithms.
- Several parameters, such as, the packet probe size, the inter packet period time, the transmission power gain, are configurable.

Difference from Related Work

- From Ganesan: In this work, substantial evidence is provided that the cause of link asymmetries is in fact due to differences in hardware calibration and an in depth analysis of the different factors affecting wireless communications in more than one environment and with more than one radio.

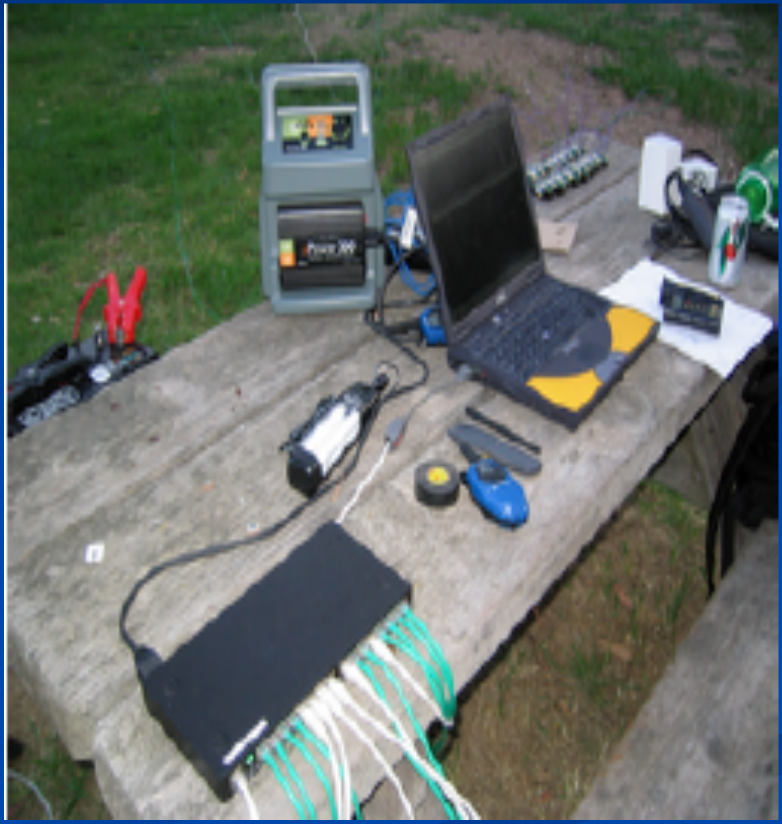
- Complementary to Woo’s work: Studies the characteristics of packet delivery in the absence of concurrent transmissions, and using more than one radio in multiple environments.
- Also Complementary to Zhao’s work: This work studies how the packet delivery is affected by packet size and using different hardware platforms.
- In ASCENT, to define some of the algorithm constants, only ad hoc values and intuition could be used for parameter tuning. SCALE fills this gap.

Contributions

- The development of a measurement and visualization tool based on an application level metric, which facilitates qualitative and quantitative characterizations of the wireless channel in a particular target environment.
- The report of quantitative and qualitative results using SCALE supplies data to support previous hypotheses in the literature, and provides new data from experiments conducted here.

System Description

- System is built using the EmStar programming model. Consists of a number of sensor nodes attached using long serial cables to one or more serial multiplexers that are connected to a standard laptop PC, with a visualization tool integrated into it.



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- When using Mica 1, a DC-balanced single-error correction and double bit error detection scheme to encode each byte transmitted by the RF transceiver is used.

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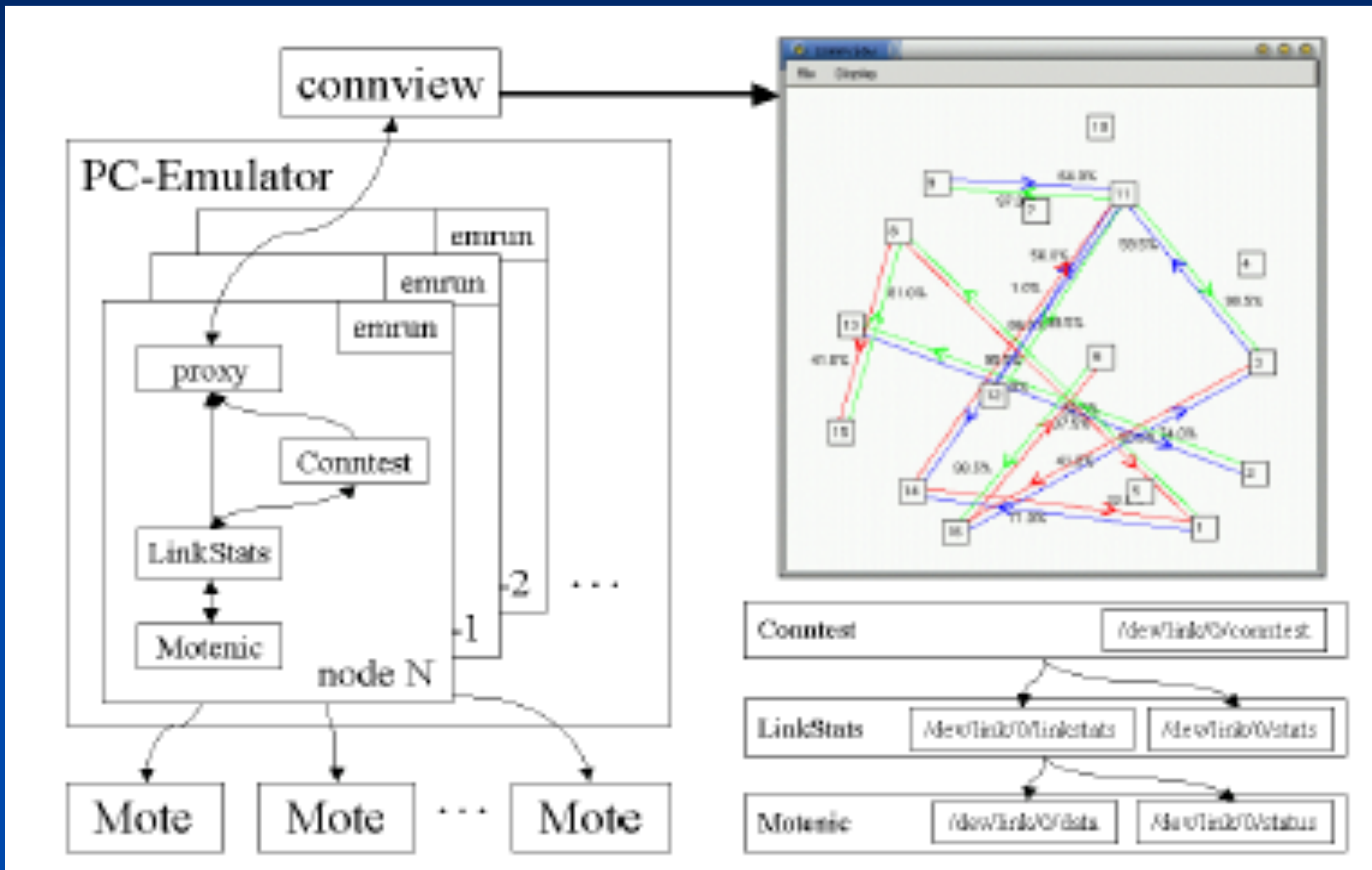
- Mica 2 relies on the hardware encoding.
- A Transceiver was used to run on the motes in TinyOS, to send/receive packets to/from the radio and pass them from/to the PC.

Software

- Each node participating in the experiment runs a software stack, which consists of a series of interconnected modules, each represented by a process with its own address space.
- Each stack runs: Conntest, in charge of sending and receiving probe packets, doing the control coordination among nodes
- LinkStats, responsible for maintaining the packet delivery statistics from all neighbors
- The low level channel driver, in charge of performing the communication with the radio.

Software Architecture



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- Two channel drivers are implemented: MoteNic, which implements the host-mote protocol to communicate to the radio over the serial port, and Udpd, which uses the UDP network interface as a communication driver. The collection of processes is managed by emrun.
- The visualization tool, Connview allows checking the state of the experiments in real-time and performing post-processing analysis.

Basic Data Collection

- Each node transmits a certain number of packet probes in a round robin fashion.
- Each probe packet contains the sender’s node id and a sequence number.
- The rest of the nodes record the packets received from each neighbor and keep updated connectivity statistics, using the sequence numbers to detect packet losses.

Methodology

- The primary measure of performance is packet loss and reception rate. The topology used in these experiments consisted of 16 nodes, distributed in an ad-hoc manner in different environments and 55 nodes distributed in the ceiling of an indoor lab.
- Nodes were placed in a variety of different positions, such as near the ground or elevated from the ground, with or without line of sight (LOS) between them, and with different levels of obstructions .

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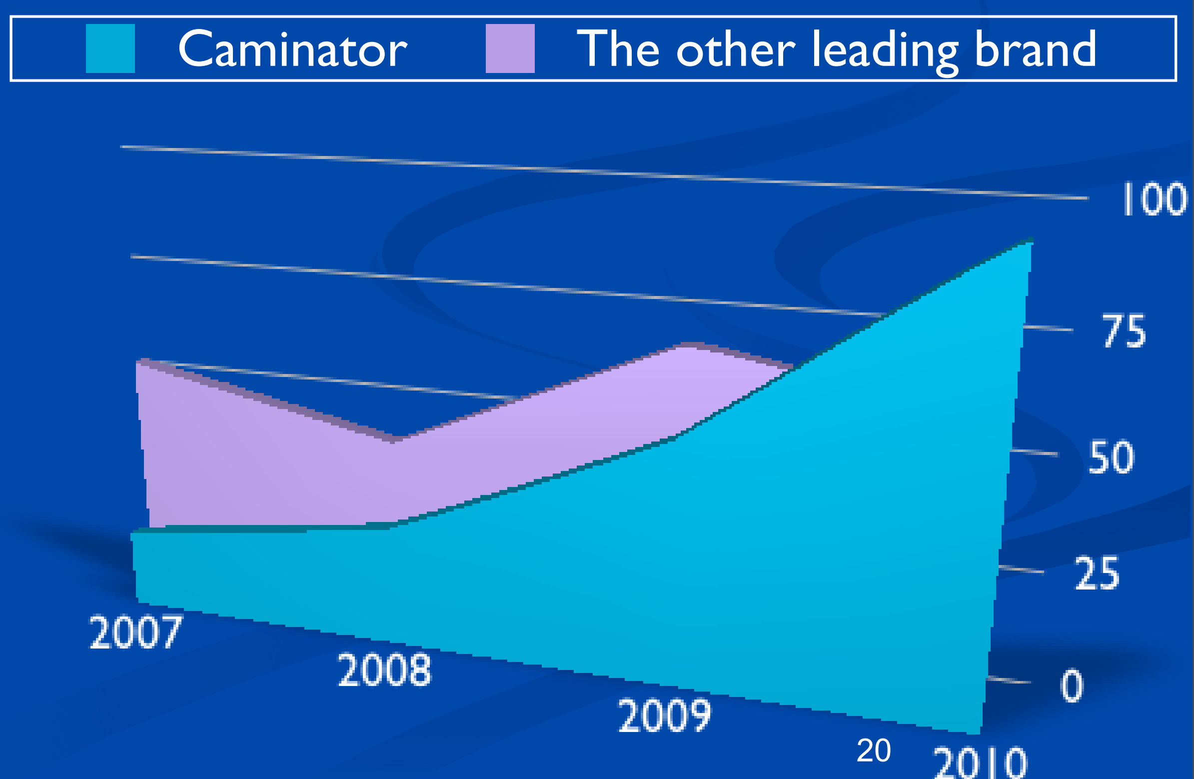
- The placement of the nodes also took into account the distance between them, in order to create a rich set of links at distances varying from 2 to 50 meters and in multiple different directions from any particular sender.
- Each node sends up to 200 packets per round, transmitting 2 packets per second.

Experiments

- Using this setup, four factors were varied in the experiments: the choice of environments, the radio type (and frequency), the output transmit power settings, and the packet size settings.

Caminator 5000

- Totally cool
- Inexpensive
- Easy to deploy
- Self-maintaining
- Dolphin friendly



Experimental Results

- Asymmetrical Links - the connectivity of node A to node B might be significantly different than from node B to node A.
- Non-isotropic connectivity - the connectivity is not necessarily the same in all the directions (same distance) from the source.
- Non-monotonic distance decay - nodes that are geographically far away from the source may get better connectivity than nodes that are geographically closer.

Spatial Characteristics

- How does reception rate vary with distance from the transmitter under different conditions and environments?
- Increasing transmission power produces an increase in reception rate at any given distance. However, it doesn't eliminate bad links.
- As distance from the source node is increased reception rate drops.
- Motes are particularly susceptible to spatial characteristics by their nature.

Link Asymmetries

- Differences in calibration and tuning seem to be the leading cause of link asymmetry.
- Look at me, not the slide.

Temporal Characteristics

- Tried multiple power levels over two hours
- When there is a high mean reception rate there is little variation.
- Low mean reception rate equals wide variation in reception rate.
- This is similar to 802.11 experiments I have made.

Transmission Efficiency

- Does packet size matter?
- No.
- Mica 1 has slightly smaller ideal packet size (150 bytes) than Mica 2 (200 bytes). Basically you can transmit large packets without it affecting reception rate.
- Default packet size is small (29 bytes) so you should consider bumping it up.

Conclusions

- SCALE is useful for measuring performance of wireless sensor networks.
- Link asymmetries are likely caused by hardware differences.
- Temporal variations of packet delivery are not correlated with distance from the source but with mean reception rate of each link.
- Distance doesn't affect reception rate in half the communication range.