Directional Radio Propagation Measurements for Near-Ground Peer-to-Peer Networks

David W. Browne, Chris Loo, Jesen Ha, Henrik Borgstrom, Michael P. Fitz, William Kaiser
Valerie Bick, Katherine Kuan, Eric Seidler, Haleh Tabrizi
University of California at Los Angeles
420 Westwood Plaza
Los Angeles, California 90095
+1 310 206 6718

decibel@ucla.edu, cloo@ucla.edu, jesen.ha@gmail.com, hborgstr@ucla.edu, fitz@ee.ucla.edu, kaiser@ee.ucla.edu

ABSTRACT
This demonstration will present a radio testbed that is being used to characterize the quality of directional peer-to-peer wireless communications in wilderness environments.

Categories and Subject Descriptors
J.2 [**Physical Sciences and Engineering**]: Earth and atmospheric sciences, Electronics, Engineering

General Terms
Measurement, Experimentation

Keywords
sensor networks, wireless communication

1. INTRODUCTION
Energy efficient wireless communications is a critical requirement for sensor networks in many environmental monitoring applications. Current sensor network simulation models and testbed implementations use omni-directional antenna for peer-to-peer communications. However, omni-directional communications is extremely inefficient in scenarios involving sparsely connected networks or scenarios with poor multipath propagation between nodes. Directional antenna promise far greater energy efficiency than omni-directional antenna and can also be leveraged for greater range or throughput. Unfortunately, very little is known about the limits of using directional radio communications in wilderness areas. This is a problem for system designers who currently plan their network deployments without assurance of the connection quality between nodes.

This demonstration will present a radio testbed that is being used to characterize the quality of directional peer-to-peer wireless communications in wilderness environments.

2. RADIO TESTBED
A testbed has been designed and built to study aspects of directional communications for near-ground sensor networks in the wilderness. A pair of prototype nodes is shown in Figure 1. The system block diagram of the transmit and receive nodes is given in Figure 2. Robots with azimuthal and elevation actuation are used to control the attitude of the directional antennas. A session of MATLAB running on the LINUX Computer (orange box) controls the receiver node components by wired connections and the transmitter node components by wireless connection over omnidirectional narrowband radio control links. Each node's power is supplied by a 12V DC battery. A tone generator at the transmitter broadcasts a single tone from the directional antenna. The tone is swept on command over a 16 MHz band in the 2.4—2.5 GHz or 5.2—5.8 GHz ranges. Downconversion of the signal at the receiver is achieved by super-hetrodyne wideband receiver. The received signal from the directional antenna is amplified, bandpass filtered and mixed from the Radio Frequency (RF) band to an Intermediate Frequency (IF) band centered at 70 MHz. This IF signal is then sampled at 500MS/s by the Data Acquisition Board, processed in MATLAB and saved to disk on the LINUX Computer. Information about timing and positioning is supplied by a GPS receiver at each node.

3. KEY CAPABILITIES
The LINUX computer may be accessed remotely through a wireless 802.11b link. The testbed is capable of running extended tests without human intervention. It is portable and ruggedized for wilderness deployments.

Measurements made with the testbed characterize link quality at the RF layer in the ISM bands (2.4 GHz, 5.8 GHz). There are currently many higher layer communication protocols used in sensor networks that make use of inexpensive ISM band radios (e.g. 802.11a/b/g, Bluetooth). Because the measurements are made at the RF layer, they are applicable to all of these higher

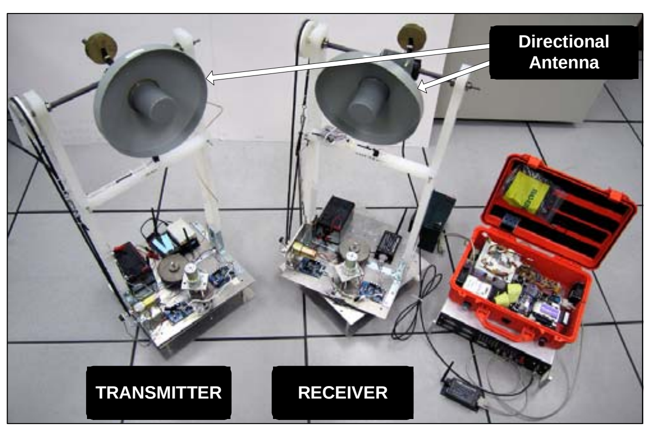

Figure 1. Transmit node (left) and receive node (right) for the Directional Communications Testbed.

WiNTECH'06, September 29, 2006, Los Angeles, California, USA.
ACM 1-59593-538-X/06/0009.

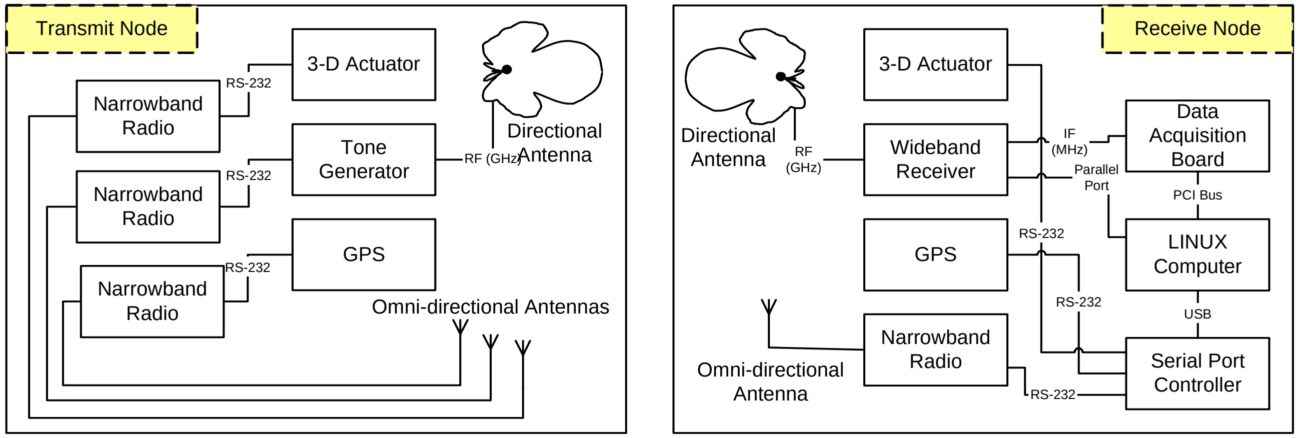

Figure 2. System block diagram of the Directional Communications Testbed transmit and receive nodes.

layer technologies and will be continue to be useable in future ISM band technologies. This is a great benefit to the system engineer who would otherwise have to repeat the measurement every time the higher layer technology evolved.

Automatic Gain Control (AGC) is achieved by a feedback control loop running on the LINUX computer that manipulated the attenuation and amplification in the Tone Generator, Wideband Receiver and Data Acquisition cards through the Narrowband Radios. This AGC solution allows measurements to be made over a wide range of propagation conditions while maintaining high Signal-to-Noise Ratio (SNR) in the acquired data.

All functionality in the system has been abstracted up to the MATLAB application layer. Experiment design is possible by programming simple MATLAB scripts. This makes the system immediately useable to a range of students and researchers with the only requirement being a basic understanding of MATLAB programming.

4. MEASUREMENT EXAMPLE

Figure 3 shows the path loss in a vegetated environment on UCLA's campus. The transmitter and receiver node antennas took measurements at 12.5 degree increments. Three direction coordinated of the transmit/receive nodes produced strong propagation paths that would be able to support high quality communication links. These paths, shown in Figure 4, correspond to the line of sight path and two weaker paths arising from reflections off buildings.

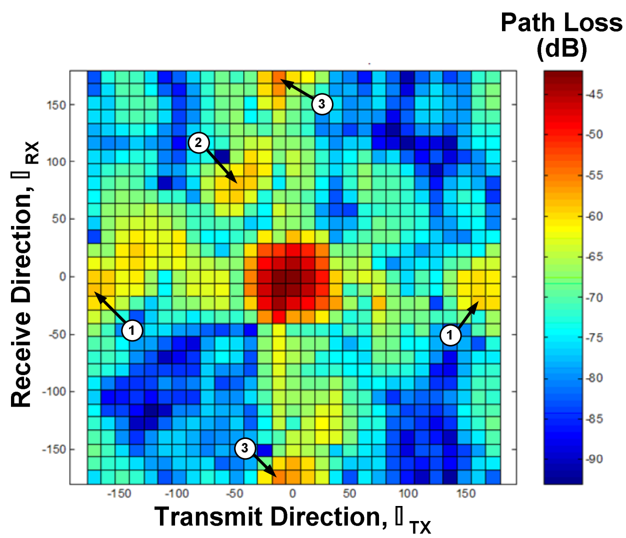

Figure 3. Measured path loss as a function of transmit and receive antenna direction in a vegetated area.

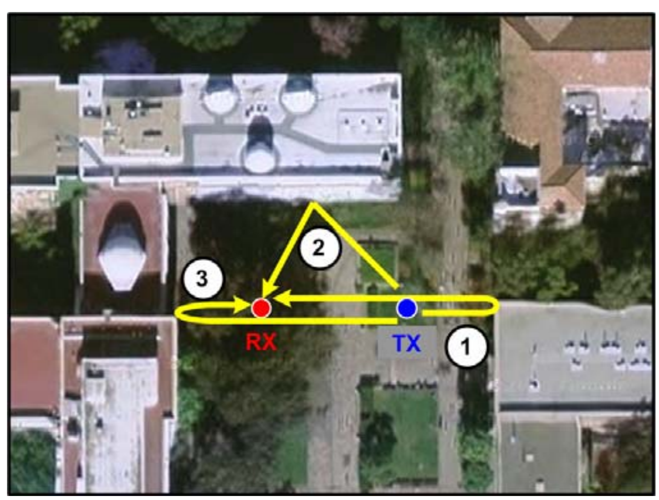

Figure 4. Arial photograph of the measurement site and node positions showing three main propagation paths.