

# A System to Monitor Signal Fade Due to Weather Phenomena for Outdoor Sensor Systems

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## ABSTRACT

Inconsistent wireless data channels due to multipath and interference are expected conditions in an office or an industrial manufacturing space. In this work we show that even ‘static’ deployments for outdoor applications will be impacted by time-varying environmental conditions. A system has been deployed outdoors at the University of Vermont (UVM) to characterize the effects of weather phenomenon on sensor network communication links. Three links were monitored, each at three different frequencies in the 2.4 GHz ISM band. While it is generally accepted that rain fade does not affect line of site (LoS) wireless systems below 10 GHz, our results indicate this does not imply that these links are completely impervious to weather related issues.

## 1. INTRODUCTION

Wireless systems in general must communicate over inconsistent data channels. For example, multipath and interference is expected in a dynamic environment such as the inside of an office or an industrial manufacturing space. In this work we show that even ‘static’ deployments for outdoor applications will be impacted by time-varying environmental conditions.

The proposed demonstration is of a system that has been deployed outdoors at the University of Vermont (UVM) to characterize the effects of weather phenomenon on sensor network communication links. The deployed system utilizes two Zigbee-compliant Chipcon CC2420DK development kits to create a four node network. The nodes were deployed on a flat roof where they have been exposed to Vermont’s winter weather (freezing rain, snow, etc.). Chipcon’s SmartRF Studio is being used for packet transmission, and Chipcon’s Packet Sniffer software is used to monitor packet reception. The wireless boards were set in a triangular configuration, with the transmitting nodes on the corners of the triangle, and the receiving node in the center of the triangle. Three links were monitored, each at three different frequencies in the 2.4 GHz ISM band. While it is generally accepted that rain fade does not affect line of site (LoS) wireless systems below 10 GHz, our results indicate this does not imply that these links are completely impervious to weather related issues.

The frequencies chosen (2.425, 2.450, 2.475 GHz) for monitoring were those determined to be quiet in terms of other traffic (e.g., WiFi, Bluetooth and UVM’s other sensor networks). 802.11b/g channels typically operate at 2.412 GHz, 2.437 GHz, and 2.462 GHz. To test the interference between these WiFi services and the WSN network, two laptops were configured to transmit data continuously using IPERF and TTCP network testing software. A

spectrum analyzer along with the sensor hardware itself was used to find the three frequencies for our WSN deployment.

Our demonstration will include the four nodes from our monitoring system along with a laptop running custom Matlab scripts to collect, store and display data. In addition to the hardware demonstration, we will present a poster illustrating the fading noted during the course of our December 2005 to April 2006 deployment along with the responsible weather conditions. The importance of these results is twofold. First, researchers must acknowledge that signal strength measurements (RSSI) made over short time intervals, will be insufficient to determine link reliability for many outdoor applications, even if the network and environment are considered static. Second, the RSSI variability noted will certainly impact the accuracy of signal strength based localization methods.

## 2. HARDWARE PLATFORM

Two Chipcon CC2420DK Zigbee development kits were chosen to measure RSSI for this work [1]. Each development kit included two evaluation boards. The evaluation boards include a USB port and diagnostic LEDs. A photo of a single evaluation board can be seen in Figure 1.



Figure 1. Chipcon CC2420DK

Power was supplied to the boards using the standard 5 Volts that the USB cable provided, although this feature was not built-in to the boards. Jumper wires were spliced to the 5 V power wires near the end of the USB cable and attached to the evaluation board. Current consumption was well below the 500mA maximum for USB allowing all four evaluations boards and the signal booster USB extension cables to be powered by the desktop computer system. Each of the USB extension cables enabled an additional 16 ft between the computer and the evaluation boards, but the plugs had to be water-proofed with heat shrink tubing and silicone caulk. The outdoor enclosures were also sealed with silicone caulk to prevent moisture from entering. To prevent winds from blowing the enclosures across the roof, a handful of rocks from the roof were placed on top of each enclosure. A photograph in which three of the nodes can be seen

appears in Figure 2. This picture was taken before the nodes were moved to their final deployment position.



**Figure 2. Chipcon evaluation board deployed in weatherproof enclosure on the roof at UVM.**

HyperLink Technologies HyperGain RE05U range extender antennas were used on each outdoor enclosure [2]. Each antenna is 152.5 mm tall and has a gain of 5 dBi. In addition, the magnetic base allowed for study weatherproof installation on the top of the enclosures. Silicone caulk was used to fill the hole where the USB and antenna cables entered the enclosure.

The software provided by Chipcon enabled straightforward packet TX/RX, along with packet error-rate calculations. Combined with Chipcon's packet sniffing software, windows macro scripting software, and MATLAB, data could now be collected over long periods of time.

### 3. DEPLOYMENT AND TEST SCENARIO

The four nodes were deployed on a flat roof at UVM. Each omnidirectional antenna was attached to the top of the weatherproof enclosures. The transmit nodes are each 6 m from the center node, and are set in an equilateral triangle configuration. Although each transmit node has LoS to the receive node, there are exhaust fans and other equipment which contribute minor multipath [3]. A photo of the rooftop deployment can be seen in Figure 3. Each node location is outlined in orange paint.

The cold weather had no noticeable effect on the performance of the hardware. In Vermont, it is not uncommon to have temperatures of  $-10^{\circ}$  F at night during the winter, and sometimes days will pass without the temperature ever going above  $0^{\circ}$  F during the day. Even during sub-zero temperatures, the evaluation boards functioned just as consistently as in room temperature conditions.

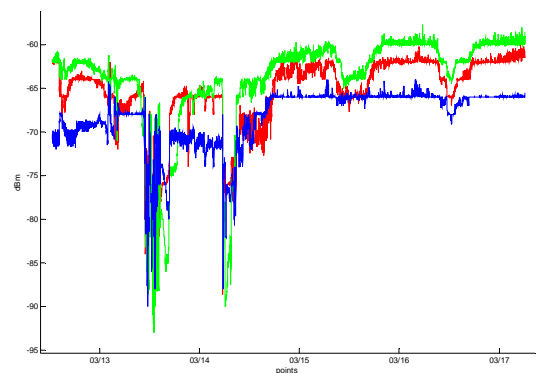


**Figure 3. Rooftop Deployment scenario. Center receive node is at position 1. Transmit nodes are each 6m from the center.**

Data was collected from December 16, 2005 to April 16, 2006. MATLAB was used to process the raw RSSI data from the Chipcon packet sniffer software, and store it in a .MAT file. Depending on the timeframe of interest, the packet collection routine could run as quickly as every 15 seconds. Most of the time, one or two minute periods were used to prevent unnecessary amounts of RSSI data, which could bog down MATLAB rather quickly. A selection of RSSI data which covers approximately five days is shown in Figure 4. The transmit nodes are color-coded to match Figure 3. Rain and overall moisture had a noticeable impact on RSSI. The two large fades in Figure 4 are caused by non-frozen precipitation. Less significant periodic fades occurred during hours of the day when the evaluation boards were affected by solar radiation.

Our test set up experienced 5-10 dB fades even during very light rainfall and snowfall. Unfortunately, and uncommon to Vermont, snowfall this winter was not enough to completely cover the deployed nodes. We have however seen that 30 dB fades in our static deployment due to freezing rain and freezing fog. During one freezing fog event, the sensor package became completely encased in ice and thus there was a complete loss of connectivity (and thus no RSSI data was logged) even over these relatively short distances (e.g., when the sensor package was encased in ice).

This research illustrates how the weather can impact wireless sensor systems that are deployed outdoors. The results are significant, particularly for systems that require high availability or RSSI based positioning. Researchers must acknowledge that RSSI measurements made over short time intervals will be insufficient to determine link reliability for many outdoor applications, even if the network and environment are considered static.



**Figure 4. RSSI at center node. Graph is color-coded to Figure 3. Rain occurred during the two large fades. Smaller periodic drops in RSSI occurred in the middle of each day.**

### 4. REFERENCES

- [1] Chipcon CC2420 Data Sheet version 1.3, Retrieved Mar. 31, 2006 from [www.chipcon.com](http://www.chipcon.com)
- [2] Hyperlink Technologies RE05U antenna Data Sheet , Retrieved Mar. 31, 2006 from [www.hyperlinktech.com](http://www.hyperlinktech.com)
- [3] Rappaport, T., Wireless communications: principles and practice, Prentice Hall, New Jersey, 1996.