Tool Release: Gathering 802.11n Traces with Channel State Information

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This article is an editorial note submitted to CCR. It has NOT been peer reviewed. The authors take full responsibility for this article's technical content. Comments can be posted through CCR Online.

ABSTRACT

We are pleased to announce the release of a tool that records detailed measurements of the wireless channel along with received 802.11 packet traces. It runs on a commodity 802.11n NIC, and records Channel State Information (CSI) based on the 802.11 standard. Unlike Receive Signal Strength Indicator (RSSI) values, which merely capture the total power received at the listener, the CSI contains information about the channel between sender and receiver at the level of individual data subcarriers, for each pair of transmit and receive antennas.

Our toolkit uses the Intel WiFi Link 5300 wireless NIC with 3 antennas. It works on up-to-date Linux operating systems: in our testbed we use Ubuntu 10.04 LTS with the 2.6.36 kernel. The measurement setup comprises our customized versions of Intel's close-source firmware and open-source `iwlwifi` wireless driver, user-space tools to enable these measurements, access point functionality for controlling both ends of the link, and Matlab (or Octave) scripts for data analysis. We are releasing the binary of the modified firmware, and the source code to all the other components.

1. MOTIVATION AND USES

It is well-known that the performance of wireless networks depends heavily on the physical layer details of the RF channel. Until recently, however, only high-level information about wireless conditions in the form of RSSI values was available from commodity 802.11 NICs. This information is of little value for understanding channel variation with mobility and for predicting successful packet delivery in different configurations of the NIC.

Fortunately, the IEEE 802.11n standard [1] defines a mechanism to pass detailed Channel State Information (CSI) between a receiver and a sender. Unlike the RSSI, the CSI captures signal strength and phase information for OFDM subcarriers and between each pair of transmit-receive antennas. This standardized CSI feedback mechanism was defined because it allows the sender to improve the link via transmit beamforming. We have co-opted this mechanism to build a measurement tool that provides a detailed picture of the wireless channel conditions.

In our work, we have used the CSI to develop a simple but accurate "effective SNR" model to predict successful packet delivery for a given transmit configuration [3]. It explains why some high-RSSI links perform poorly, and enables accurate selection of 802.11n rates and transmit power levels across a wide variety of real wireless links.

Other researchers might use the CSI measurements in many ways, such as to diagnose real-world 802.11 network problems or to evaluate alternative wireless designs. CSI traces might help to evaluate the impact of external interference, to evaluate advanced techniques like multi-user MIMO, or to understand the impact of channel fading in vehicular Wi-Fi networks. These are only samples; we expect the community can develop all sorts of creative uses.

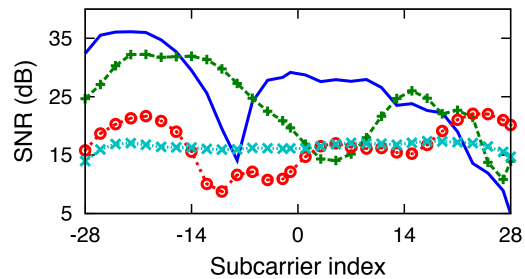

Figure 1: Subcarrier-level signal strength computed from channel state information for four single-antenna 802.11n links.

2. HOW IT WORKS

Every 802.11n NIC measures the channel state for each received packet during the packet preamble. The CSI is then used in the equalizer to compensate for channel effects before demodulation. Our firmware modifications enable an Intel debug mode that records CSI for each correctly received 802.11n packet and sends it up to the kernel driver on the host computer. The driver in turn passes the CSI to a user-space program for processing.

The Intel 5300 NIC reports CSI for 30 groups of subcarriers, spread evenly among the 56 subcarriers of a 20 MHz channel or the 114 carriers in a 40 MHz channel. Figure 1 shows representative CSI for four single-antenna links that offer equivalent performance but differ in RSSI by up to 13 dB. With CSI, we can clearly see the extent of frequency-selective fading. Weak, deeply faded subcarriers require the transmitter to expend more power to deliver the same performance, driving the necessary RSSI higher.

In two typical use cases the user-space code can process the data as part of an online algorithm, or simply dump the trace to disk for later processing. We provide Matlab utilities to parse the standardized CSI format [1, §7.3.1.28] and to compute standard features such as the channel's singular value decomposition and its MIMO condition number. These provide a basic understanding of MIMO wireless channels, and can serve as a basis for further development.

3. MORE INFORMATION

To download this tool and for more information, please see: `http://ils.intel-research.net/projects/80211n-channel-measurement-tool`. We welcome inquiries from potential users and feedback. To learn more about 802.11n and MIMO fundamentals, we refer the reader to a short tutorial in last January's *CCR* [2].

4. REFERENCES

[1] IEEE Std. 802.11n-2009: Enhancements for higher throughput. `http://www.ieee802.org`, 2009.

[2] D. Halperin, W. Hu, A. Sheth, and D. Wetherall. 802.11 with multiple antennas for dummies. *ACM SIGCOMM CCR*, 40(1), January 2010.

[3] D. Halperin, W. Hu, A. Sheth, and D. Wetherall. Predictable 802.11 packet delivery from wireless channel measurements. *ACM SIGCOMM*, 2010.