A Real Time MIMO OFDM Testbed for Cognitive Radio & Networking Research

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ABSTRACT

A real time, 2 Mbps to 200 Mbps portable radio unit with MIMO and sensing capability which exposes all the PHY parameters to the higher layers will help advance experimental cognitive radio (CR), and wireless networking research. Collaboration between Silvus Communication Systems and the UCLA WISR group has resulted in the first generation radio specifically designed to meet the needs of the CR and wireless networking community. The current platform is based on a COTS FPGA platform with dual-band RF capabilities. It implements a slight variant of the 802.11n draft spec. It is a fully self contained PHY solution with over 100 unique modes of operation. Moreover it features a robust API to the MAC through which all PHY parameters can be controlled on a per-packet basis. The same API will allow the PHY to communicate channel state information, SNR, and RSSI measurements to the MAC. A 16 micro-second packet decode latency ensures that the PHY processing does not inhibit the system's fast response to changing channel and interference conditions

Categories and Subject Descriptors

B.1.m [**Hardware**]: Miscellaneous.

General Terms: Experimentation

Keywords

Testbeds, wireless networks, 802.11n, MIMO OFDM

1. INTRODUCTION AND MOTIVATION

Development of wireless networks include many phases, but invariably verification on a practical testbed or prototype is needed to validate the theoretical and simulation work. Such prototype systems are used not only for verification of derived theory, but increasingly some concepts can only be seriously studied in practice (e.g. interference modeling). As communications theory pushes towards higher bit rates, the design and development of testbeds that can support the high throughput gets more challenging in a research environment. Consequently network and cognitive radio researchers are forced to adopt commercial platforms such as 802.11 based systems for their research needs. These platforms seldom provide the researchers full control of the RF, PHY, and lower MAC functionalities. Moreover, they do not allow any changes to the underlying framework. Our prototype system, was designed specifically to address these needs. The first version of this prototype, which is being demonstrated at WiNTECH, provides many of the above mentioned requirements. Future versions of the prototype will deliver even greater functionality and a more intuitive MAC/PHY API.

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2. TESTBED HIGHLIGHTS AND FEATURES

Our efforts produced a real time MIMO OFDM testbed that can satisfy the needs for both the cognitive radio community and the traditional wireless networking community. The testbed was implemented on a single Virtex-II FPGA with real time capabilities. It was developed to support a large number of permutations of physical layer modes (see table 1). It supports a slight variant of the IEEE 802.11n draft proposal [1]. Data rates supported range from as high as 200Mbps to as low as 2Mbps in an over the air bandwidth of 20 MHz, allowing prototypes for intelligent spectral allocation, high throughput testbeds, and testbeds whose main concern lies beyond raw throughput. Figure 1 shows the current form factor for the testbed.

Table 1 – Radio features for first generation testbed

Bandwidth	5, 10, 20 MHz	Constellation size	2-, 4-, 16-, 64-QAM
No. Antennas	1x1, 1x2, …, 2x4, …. 4x4	Coding Rate	½, 2/3, ¾, 5/6
Type of Antenna processing	Spatial MUXing, Space-Time Coding, Diversity, Smart Ant.	Spatial Multiplexing Decoder	Modified MMSE
Modulation	OFDM (64 point FFT)	No. Sp. Streams	1, 2, 4

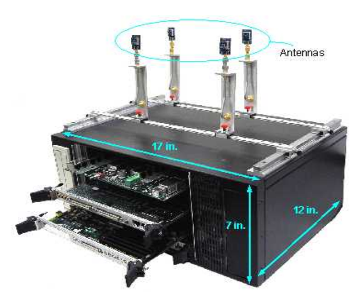

Figure 1 – The first generation testbed (both baseband and RF) is built into a cPCI chassis measuring 17"x 8"x 12"

The testbed can support any combination of the parameters shown in Table 1. These modes are defined by the MAC through an API interface that header of each MAC to PHY transmission to contain the value of the configuration registers for that specific packet. In this manner, the higher layers can dictate exactly the type of packet and mode that is to be used. In the reverse direction, the PHY can provide CRC results, SNR, RSSI, and channel state information to the MAC and networking layers to enable advanced protocols.

The next version of the prototype will allow independent allocation of the RF transceiver chains. This will allow any number of antennas to be used for transmission while the others are engaged in channel sniffing as per cognitive radio research needs.

3. IMPLEMENTATION CHALLENGES

Real time MIMO decoding was a major bottleneck in the transceiver. MIMO decoding is very compute intensive [2], [3]. A typical 4X4, 20 MHz implementation could easily claim as much as half the overall transceiver resources. Given the limited resources of an FPGA, an untraditional approach was necessary. Our approach involved using multipliers to complete an implicit inversion. While suboptimal for an ASIC implementation, the abundance of dedicated multipliers on an FPGA makes this approach viable and relieves the demands of the decoder on other FPGA resources. Our requirement of a single FPGA implementation required significant hand coding of the RTL to ensure maximum reuse and an efficient implementation. It is expected that an automated system-generator based methodology would easily yield a solution that was 4x larger than the current baseband implementation. Figure 2 shows the top level functional block diagram of the receiver. The transmitter follows an 802.11n type of packet structure and protocol.

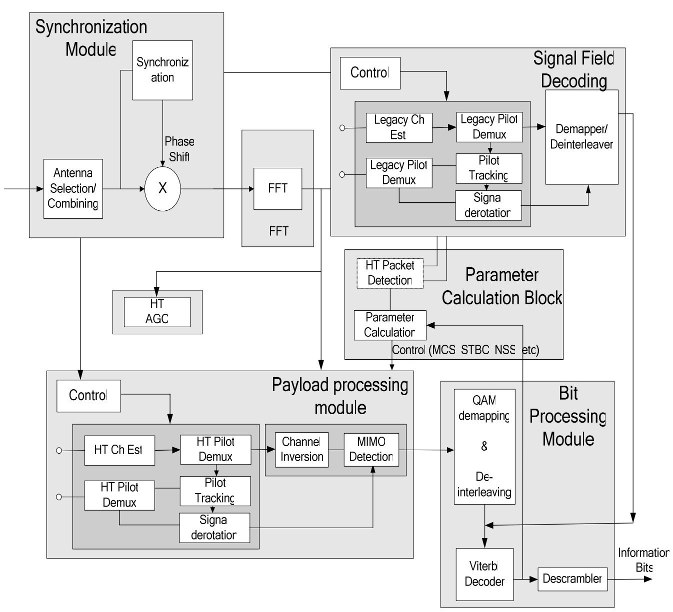

Figure 2 Top level block diagram for the receiver

The RF portion of the testbed is centered around the MAXIM 2829 dual band 2.4/5.8 GHz transceiver. The current testbed uses evaluation kits for many of the RF components, but work is currently underway for a single board quad RF transceiver module.

4. TESTING METHODOLOGY

Before writing the HDL code, a complete floating point simulation for the end-to-end system was developed in MATLAB. A fixed point simulation for the whole system was also developed and it proved invaluable in choosing precision for building blocks, as well as providing a bit matching test for the practical system.

Figure 3 shows an example of a fixed point study. In this example, the performance of the whole system using an MMSE MIMO decoder with 14 and 16 bits resolution was compared with the floating point performance. Practical tests proved that the system matches fixed point simulations bit by bit, in all modes, and for long or bursty transmission periods.

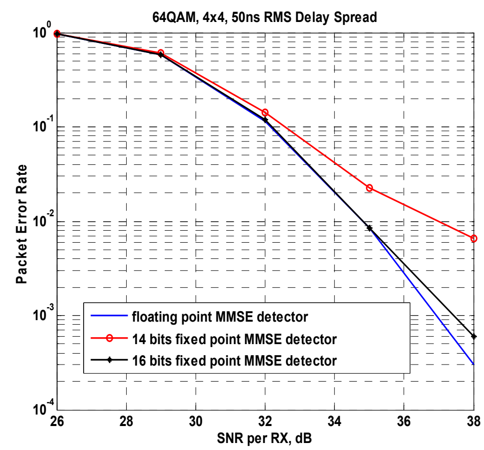

Figure 3 Floating and fixed point MIMO detector simulation

5. THE DEMONSTRATION

As part of our WiNTECH demonstration we will show an RF (over the air) transmission of data using arbitrary modes. Specifically Twenty packets will be sent from the transmitter to the receiver, and every packet will be sent using a different physical layer mode. On the receiver side, a GUI will provide insights into the performance of each packet (consequently each mode), for example receiver SNR, BER, PER, and channel Eigenvalues allow side by side comparison in real time of all the tested modes. Modes will be changed in real time and channel conditions and impairments will be introduced to highlight research scenarios in which this testbed would prove a valuable asset.

6. REFERENCES

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