Exploring RFID Prototyping in the Virtual Laboratory

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1 Introduction

Radio frequency identification systems have recently gained popularity for a wide variety of applications including supply chain management, asset management, and barcode replacement. To train RFID engineers, several Universities have developed training courses, concentrations, or certificate programs. Often, students can complete these courses or programs without having touched a single RFID reader. Part of the difficulty is the cost of and limited availability of RFID systems and analysis equipment.

This paper describes several RFID technology related course topics dealing with antenna design, protocol design, and implementation strategies accessed from a centralized system for students to access. By utilizing the central system, students from multiple universities can share a single piece of equipment and still learn about the underlying RFID technology. Additionally, by creating this interface system, the necessary features for RFID development can be made available to students and instructors need not learn every single detail of complicated equipment to effectively teach students to work with RFID technology.

2 RFID Course Description

The motivation for our RFID course grew out of the combination of a wireless communication course taught at the University of Pittsburgh and fundamental research in RFID. This course was built on two fundamental educational innovations used in the wireless course. Rather than using a given text for the course as they are typically not available or out of date for cutting edge technology courses, students are required to write and submit portions of their own text based on the course material to the CASCADE (Computer Augmented Support for Collaborative Authoring and Document Editing) system allowing them to more effectively learn the material. Also, a web-based virtual laboratory was employed as a way to provide time-shared access to expensive laboratory equipment that allows complete access to the software and hardware systems while providing a protected environment for the equipment. The new components are described in the following sections:

2.1 Automated RFID Tag and Reader Generation

RFID transactions between a reader and tag are based on a set of commands or primitives. We have developed a design automation tool, shown in Figure 1, that automatically translates these primitives into a controller for an RFID tag for microprocessor, FPGA, or ASIC targets [1]. Students use our RFID specification language to generate RFID macros with behavioral descriptions written in C that correspond to primitives from the students RFID specification. The RFID Compiler, generates the tag controller code C or VHDL depending on the target hardware. The tag can be simulated for correctness either using a given reader input file or based on a standard specification. We have demonstrated this for Intel StrongARM, XScale, and ADCUS EISC microprocessors; Altera Apex, Xilinx Spartan 3, and Actel Fusion FPGAs; Xilinx Coolrunner 2 CPLDs; and Oki 0.16 μm cell-based ASIC technologies. The program can also be downloaded into either a microprocessor (EISC) or FPGA (Spartan 3) prototype with an attached air interface to be tested with a reader. It is also possible for a student to supply their own VHDL or C programs and to bypass the design automation if desired.

2.2 Real-time Spectrum Analysis for RFID

In order to test prototype RFID Tags and Systems, a simulation environment for the system has been constructed based on hardware and software from National Instruments (NI) and VI Service Networks [3]. NI has created an FPGA prototyping board based on a Xilinx Virtex II Pro FPGA. An overview, shown testing the ISO 18000 Part 6C standard “query” command is shown in Figure 2. This system can be used by students to test their designs from Section 2.1. The board (NI PCI-5640R IF) also contains a 14-bit ADC/DAC which integrates into the NI RF equipment shown in Figure 2(a). The NI RF equipment downconverts the UHF transceivers that operate at 433 and 915 MHz to an intermediate frequency compatible with the FPGA board. The Labview RF visualization software is particularly valuable for testing prototype systems that use RF communication as it shows frequency power spectra over time, see Figure 2(b). Utilizing the FPGA Transceiver
board, the simulation environment for RFID systems is configured so that it emulates a real-time communication channel between the reader and the tag.

3 Results, Conclusions, and Future Work

Using the techniques described in Section 2, tag controllers have been generated and profiled for the ISO 18000 Part 7, ANSI 256, and ISO 18000 Part 6C RFID standards as well as combinations of these standards (specifically ISO 18000 Part 7 and ANSI 256) and augmented systems including one or more standard and custom primitives created by the student. To verify correctness, programs have been downloaded to several implementation targets including an EISC microprocessor-based prototype and a Spartan 3 FPGA-based prototype. An ISO 18000 Part 6C design has also been downloaded to the Virtex II FPGA board and tested with the NI equipment and LabView software.

For example, a completed project used the course infrastructure to compare the complexity of two equivalent commands from ISO 18000 Part 6C (query) and ISO 18000 Part 7 (collection). In this case, equivalence means the commands serve the same purpose, discover what tags are within range of the reader. However as shown in Table 1, the behaviors are actually quite different. The collection command and 9 other commands from ISO Part 7 require less power and area than the query command from ISO 18000 Part 6C.

Currently, our system does allow power and range analysis of the RF transmission portion of the tag but unlike the digital portion of the tag, the transceiver and protocol are fixed. However, we plan to generate a similar design automation tool to the RFID compiler to explore the use of different communication protocols such as Manchester, FM0, PIE standard encodings as well as custom encodings built from scratch. This will allow students to examine the physical layer in the same manner as they explore RFID transaction standards. We also plan to expand the number of prototype system targets, and add the capability of including sensors and security features to the system.

Table 1. Power and energy results for implementing Query, Collection and 10 ISO Part 7 primitives with a 0.16μm ASIC.

<table>
<thead>
<tr>
<th>Primitives</th>
<th>Dynamic Power (mW)</th>
<th>Area (100μm²)</th>
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<tbody>
<tr>
<td>Query</td>
<td>0.06752</td>
<td>11767.46</td>
</tr>
<tr>
<td>Collection</td>
<td>0.06308</td>
<td>10944.83</td>
</tr>
<tr>
<td>10 primitives</td>
<td>0.06495</td>
<td>11232.92</td>
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References