Reconfigurable Software Defined Radio and Its Applications

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Abstract

Currently, most Software Defined Radio (SDR) related products and researches focus on analog communication and voice transmission. In this paper, we propose a SDR platform with digital data communication capability. This platform consists of Field Programmable Gate Array (FPGA) based radio hardware and open source SDR software modules. The main features include: 1) Radio Spectrum Sensing; 2) Reconfigurable Radio Modules; 3) Link for Digital Data Communication. Based on the proposed SDR platform, we could easily reconfigure its radio modules and discover the spectrum hole to achieve better communication quality. These features are important basis to accomplish Cognitive Radio (CR) technologies.

Key Words: Digital Data Communication, Spectrum Sensing, Software Defined Radio, Cognitive Radio

1. Introduction

The mature development of radio technology brings novel wireless applications into people’s life. The mobile devices can afford the high speed and complex computation owing to the advance in computing ability of the processor, such as PDA (Personal Digital Assistant), Smart Phone, or UMPC (Ultra-Mobile PC). Most of these mobile devices equipped with Wi-Fi, WiMAX or other wireless modules making people be able to access services anywhere. However, different radio technologies and protocol standards need to be realized through different IC (Integrated Circuit) chips. How to integrate the various protocols and radio frequency (RF) chips into a small device is the most important challenge in recent years. Therefore, there is a design trade-off between the application variety and the size minimization of user device.

The traditional hardware radio system consist a variety of analogy elements such as filters, converters, modulators and demodulators. The hardware is expensive in cost and low compatibility with other components. The reason why Software Defined Radio (SDR) becomes popular is that people could use SDR technology to realize many applications without a lot of efforts in the integration of different components. We can change the different software module to adapt different modulators and demodulators in the SDR platform. The most radio and wireless related applications could be achieved.

Users can use SDR on personal wireless device. For example, the vendors could integrate GSM (Global System for Mobile Communications), WCDMA (Wide band Code Division Multiple Access), GPRS (General Packet Radio Service), IS-95, EV-DO, Wi-Fi, WiMAX or Bluetooth in a single device and update the newest radio modules by download software modules. In the military applications, such as U.S. DoD Joint Tactical Radio Sys-
tem (JTRS) program [1] develops a military radio communication device which supports more than 20 different communicational standards. In an emergency situation, the gateway device based on SDR could be used to bridge various types of incompatible radio equipments or establish a temporary communications infrastructure through SDR equipment.

Therefore, the goal of the user device development is to minimize its size, decrease the number of ASIC chips but keep more radio applications. To achieve the software radio functions, the base protocol of software modules, ADC/DAC conversion of hardware radios and multi-band antennas are necessary. Although the concept of SDR has been proposed for a long time, the implementation was stuck due to the insufficient technology until recent years. Most products and research developments of SDR focus on the voice transmission. This paper utilizes Universal Software Radio Peripheral (USRP) [2] and GNU Radio [3] to implement a reconfigurable SDR platform which can support digital communications and wireless spectrum sensing.

This paper is organized as follows. We introduce the available SDR resources and our platform, including the design of GNU Radio and the architecture of USRP in section 2. The radio spectrum sensing and the reconfigurable digital communication, the implementation and experiment results are showed in section 3. Conclusion are finally drawn in section 4.

2. Background

2.1 Software Defined Radio

Traditional hardware radios are implemented with analog and solid poly-Si elements. In SDR, the traditional hardware is replaced by software modules such as Figure 1. SDR was proposed by Joseph Mitola in the beginning of 1990 [4]. Unlike adopt Application Specific Integrated Circuit (ASIC) to implement radio elements in the past, the technologies such as Field Programmable Gate Array (FPGA), Digital Signal Processor (DSP) and General-Purpose Processor (GPP) are used to build the software radio elements. These components have reconfigurable capability which making these components tend to generalization in order to implement a variety of different radio applications.

The fundamental architecture of SDR is shown in Figure 2. It includes front-end, processing engine and application. The Radio Frequency (RF) front-end module digitizes the radio frequency data from antennas. After the baseband is digitized by front-end, the processing engine converts baseband data and date frames. The application side receives data frames at last.

2.2 USRP

Universal Software Radio Peripheral (USRP) was designed by Matt Ettus [2]. It was combined with radio front-end, Analog to Digital Converter (ADC) and Digi-
tal to Analog Converter (DAC) via Universal Serial Bus (USB 2.0) on GPP platform. According to the statements as mentioned above, the USRP is available to realize a reconfigurable and adaptable SDR.

Figure 3 shows the components on USRP motherboard. The 4 ADCs which can sample $60 \times 10^6$ times per second on each ADC, and 4 DACs which samples $128 \times 10^6$ times per second on every DAC. Additionally, there are one Altera Cyclone EP1C12 FPGA chip and one programmable Cypress FX2 USB 2.0 controller on the USRP motherboard.

In USRP, the block diagram as shown in Figure 4 represents whole work flow and function components. It can be divided into two parts based on the transmission path. There are transmitting signal path and receiving signal path. For example on transmit signal path, users can define the setting parameters by software on personal computer such as radio protocols, modulation types, frequency of spectrum modulation. Then the USRP receives the parameters, and FPGA executes Intermediate Frequency (IF) processing on Digital Up Converter (DUC) and Digital Down Converter (DDC). After IF process, users adjust the baseband to the frequency band selected before. The last step on USRP motherboard is that DAC converts the digital signal into analog signal. Finally, the analog signal is transmitted to the antenna through the interface side A or side B on the daughterboard. According to the above procedure, we can confirm that one per-

![Figure 3. USRP motherboard.](image)

![Figure 4. USRP block diagram.](image)