UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF A MULTI-STANDARD PROTOCOL USING SOFTWARE DEFINED RADIO FOR A MOBILE STATION TRANSCEIVER

KHALID ELTAHIR MOHAMED OSMAN

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By

KHALID ELTAHIR MOHAMED OSMAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, In Fulfilment of the Requirement for the Degree of Doctor of Philosophy

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DEDICATED

…My dearest mother…. for making out of me the
person who can present such a work...for doing all this with pleasure……

…. My beloved wife Amani…. the person who leads to
successful life…and gives me all her supports and cute kids…..

To all the glory inside you…

To you…
…love…thanks…and my simple effort…

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

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Chairman: Professor Borhanuddin Mohd. Ali, PhD

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In this thesis, the Software Defined Radio Digital Control System (SDR DCS) has been developed to perform a multi-standard protocol of the handset using the GSM and CDMA systems. The SDR DCS was designed for the SDR based band digital transceiver of the handset as a control and protocol software to control and handle the operation of the handset when roaming between different protocols; it could easily and quickly let the handset reconfigure with the future protocol; it configured the handset with either of the GSM or CDMA protocol software, and scheduled for reconfiguration of the handset with the second protocol in sequence. The SDR DCS controls the download of the specific air interface environment.

In order to implement the whole design in software, the design had to go through three stages. The first stage was to do all the design steps in the software using generic computing resources such as Hardware Description Language (HDL), with the top-level design for each protocol. The second stage was to define a logic circuit to perform the signal processing for each protocol; this step was applied after the simulation and synthesis, and eventually programming that circuit into the FPGA

board. The third stage was to use the FPGA to implement the functions required for each protocol which constitutes the multi-standard protocol.

The VHDL files were created for each element of the GSM and CDMA protocols. The GSM related system was developed with encoders and decoders linked to the channel model. The CDMA related system was designed with a transmitter to encode the user's data into wide bandwidth using a reverse link channel and a synchronized receiver to receive the signal from the forward link channel and decode the wide bandwidth to recover the base band user's data.

The Synopsys™ software package was used for the design, synthesis and simulation of the SDR base band platform. The simulation tools used include the Model Sim and System Studio. Meanwhile, the Xilinx ISE 9.2i was used as the synthesis tool. The results of the simulated and synthesized top-level design files were downloaded into the Xilinx XSA-3S1000 FPGA board. The waveforms for the GSM and CDMA outputs approximately matched the ones seen in the oscilloscope for the FPGA output pin. This proved that the SDR DCS had successfully implemented its task, according to the objectives of the design.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

REKABENTUK DAN PELAKSANAAN PROTOKOL BERBILANG PIAWAIAN UNTUK TRANSCEIVER STESYEN BERGERAK RADIO BERDEFINISIKAN PERISIAN (SDR)

Oleh

KHALID ELTAHIR MOHAMED OSMAN

Mac 2009

Pengerusi : Profesor Borhanuddin Mohd. Ali, PhD

Fakulti : Kejuruteraan

Dalam tesis ini, Sistem Kawalan Digital SDR (SDR-DCS) telah dibangunkan untuk melaksanakan protokol berbilang piawaian untuk telefon bimbit menggunakan sistem GSM dan CDMA. SDR-DCS telah direkabentuk untuk transceiver jalurasas digital berasaskan SDR untuk telefon bimbit supaya ia dapat merayau di antara bcrbagi sistem tanpa-wayar. SDR DCS dengan mudah dan cepat membenarkan telefon bimbit mengatur semula dengan protokol yang baru ini; ia mengatur semula telefon bimbit dengan salah satu dari perisian protokol GSM atau CDMA, dan menjadualkan untuk mengatursemula telefon bimbit dengan protokol kedua, dalam jujukannya. Sebagai kesimpulannya, SDR-DCS mengawal muat-turun persekitaran pengantaramuka udara tertentu.

Untuk melaksanakan keseluruhan rekabentuk dalam perisian, rekabentuk tersebut akan melalui tiga peringkat. Peringkat pertama ialah melakukan kesemua langkah rekebentuk dalam perisian menggunakan sumber pengkomputeran umum, iaitu fail Bahasa Pemerihalan Perisian (HDL) untuk rekabentuk. Peringkat kedua ialah mendefinisikan suatu litar logik untuk melakukan pemprosesan isyarat bagi setiap

protokol; langkah ini diaplikasikan setelah selesai simulasi dan sintesis dan diakhiri dengan pengaturcaraan litar tersebut pada papan FPGA. Peringkat ke tiga ialah untuk menggunakan FPGA bagi melaksanakan fungsi-fungsi yang diperlukan untuk setiap protokol yang menjadikan ia protokol berbilang piawaian.

Fail VHDL telah dibentuk untuk setiap unsur protokol GSM dan CDMA. Sistem berkaitan dengan GSM telah dibangunkan dengan pengekod dan penyahkod yang dikaitkan dengan model saluran. Sistem berkaitan dengan CDMA telah direkabentuk dengan satu penghantar untuk mengekod data pengguna kepada lebarjalur yang luas menggunakan saluran pautan songsang dan satu penerima segerak untuk menerima isyarat dari saluran pautan kehadapan, dan menyahkod lebarjalur luas untuk mendapatkan balik data pengguna.

Package perisian Synopsys telah digunakan untuk merekabentuk, mensinthisis dan mensimulasi platform jalurasas SDR. Alat simulasi yang digunakan adalah Model Sim dan Sistem Studio. Xilinx ISE 9.2i telah digunakan sebagai alat sintesis. Hasil keputusan dari fail aras utama yang disimulasi dan disintesiskan telah dimuat turun kepada papan Xilinx XSA-3S1000 FPGA. Bentuk gelombang untuk GSM dan CDMA adalah hampir serupa dengan apa yang dapat dilihat dari oscilloscope untuk pin keluaran FPGA. Ini membuktikan bahawa SDR-DCS telah berjaya melaksanakan tugasnya mengikut objektif rekaan.

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I certify that an Examination Committee met on 11th of March 2009 to conduct the final examination of Khalid Eltahir Mohamed Osman of his Doctor of Philosophy thesis entitled "Development of a Multi Standard Protocol Using Software Defined Radio for Mobile Station Transceiver" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination committee are as follows:

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DECLARATION

I declare that the thesis is my original work except for the quotations and citations, which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institutions.

KHALID ELTAHIR MOHAMED OSMAN

Date: 15 July 2009

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ADC	Analog to Digital Converter
AIS	Air Interface Standards
ASIC	Application Specific Integrated Circuits
CDMA	Code Division Multiple Access
CORBA	Common Object Request Broker Architecture
CRC	cyclic redundancy checks
DAC	Digital to Analog Converter
DDC	Digital Down Converter
DKI	Direct Kernel Interface
DoD	US Department of Defense
DS	Direct Sequence
DSP	Digital Signal Processor
DUC	Digital Up Converter
EDA	Electronic Design Automation
IF	Intermediate Frequency
IS-95	Interim Standard 95
ISE™	Integrated Software Environment
ITU-R	International Telecommunication Union - Radio
FCC	Federal Communications Commission
FPGA	Field Programmable Gate Array
FSM	Finite State Machine
JTRS	Joint Tactical Radio System
GSM	Global System for Mobile
GPRS	General Packet Radio Service

LFSR	Linear Feedback Shift Register
MS	Mobile Station
NCD	Native Circuit Description
NGD	Native Generic Database
OTA	Over-The-Air
PAR	Place and Route
PCF	Physical Constraint File
PN	Pseudo-Noise
RAM	Random Access Memory
RF	Radio Frequency
ROM	READ Only Memory
RTL	Register Transfer Level
SCA	Software Communication Architecture
SCR	software controlled radios
SDR	Software Defined Radio
SDR DCS	Software Defined Radio Digital Control System
SOC	System-on-Chip
UMTS	Universal Mobile Telecommunications System
UPM	Universiti Putra Malaysia
VCS	Verilog Compile Simulator
VHDL	Very High Speed Integrated Circuit (VHSIC) Hardware Description Language

CHAPTER 1

INTRODUCTION

This chapter introduces the subject of multi-standard protocol for Software Defined Radio (SDR), the main requirement that must be satisfied by the multi-standard SDR and its capability to support the communication system applications. There are numerous definitions given to the SDR, all of which are not totally consistent with each other. Among other, International Telecommunication Union - Radio (ITU-R) defines the SDR as "A radio that includes a transmitter, in which the operating parameters of frequency range, modulation type, and/or maximum output power (either radiated or conducted) can be altered, post-manufacturing, by making a change in software or adapting parameters under software direction, without making changes to the hardware components". The Federal Communications Commission (FCC) defines the SDR as a "generation of radio equipment which can be reprogrammed quickly to transmit and receive any frequency within a wide range of frequencies, using virtually any transmission format and any set of standards". In contrast, the SDR Forum, as an international, non-profit organization promoting the development of SDR, offers a broader definition, i.e. "SDR is a collection of hardware and software technologies which enable reconfigurable systems architectures for wireless networks and user terminals".

1.1 Research Motivations and Problem Statements

Wireless communication systems are rapidly evolving through the incessant extension of the old standards (GSM, IS95, CDMA2000, and UMTS) with the new

generations. A side effect of this rapid growth is an excess of mobile system standards; every major country has its own standards.

In present day environment, there is a wide range of wireless communication systems available such as the GSM, CDMA, WiFi etc. To support such diverse set of protocols and the associated payloads (voice only with the GSM; voice, graphics, video with 3G), most mobile handsets are built with multiple RF transceivers and DSP chipset or microprocessors to handle the complex signal processing requirements.

In the present technology, a handset is moved from one environment to another, for example from GSM to CDMA; the handset devices simply "switch" the receiver and transmitter circuits for the predefined air interfaces, rather than employing a single, common RF front end. If a particular interface is not built into the handset, it is not possible for the handset to operate in that particular environment. In such cases, the consumer will have to purchase a different unit.

With the rapid development and growth in mobile telephone usage, it is clear that a wireless revolution is taking place. The users' problem is one of connectivity and a growing number of incompatible Air Interface Standards (AISs) as well as information filtering. At their desks, users have email, telephones, personal computers, and wideband connectivity to internal backbones and external services. As they leave their offices, they have to rely on their personal computers for notification and cellular phones for contact. Both of these devices, however, have limited access areas and specific protocols. Users also have separate palmtop devices for multimedia information capture, storage, and display; these devices incorporate substantial computational power.

Traditional radios use hardware circuits, fixed at time of manufacture to perform the high speed signal processing to convert back and forth between user data and radio waveform. In a traditional cell phone, for example, there is the radio front end, consisting of an antenna and a radio-frequency transceiver that picks up the analog radio waves, filters out the unwanted portions of the spectrum, and converts the remainder into a lower frequency signal, which is fed into an analog-to-digital converter. The resulting baseband signal is then processed i.e. demodulated, decompressed, or otherwise decoded.

In a hardware radio (HDR), legacy platforms are tailored to support only one type of waveform. That is, the physical layer of the waveform was embedded in specific hardware solutions and the Radio Frequency (RF) front end was also optimized for the same waveform. The key architectural elements of a radio would be the transmitter and receiver (or transceiver), RF power amplification, and encryption/decryption.

Within a Software Defined Radio (SDR), the radio contains several processing elements (General Purpose Processors (GPP), Digital Signal Processors (DSP), and Field Programmable Gate Array (FPGA)) that can be programmed by the waveform to deliver the required functionality. However, if each waveform must be tailored to the specific unique capabilities of each individual platform, (e.g., the type of GPP, DSP, and FPGA), significant portions of the waveform may have to be rewritten if they need to be ported to different hardware platforms. This has prompted the development of open standards, to make it easier to develop waveforms that can run on multiple platforms with minimal change.

Software defined radio aims to get rid of most of that hardware. A number of companies are working on reconfigurable RF chips that can directly convert any