Software Defined Radio

Architectures, Systems and Functions

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West Sussex PO19 8SQ, England

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John Wiley & Sons Inc., 111 River Street, Hoboken, NJ 07030, USA

Jossey-Bass, 989 Market Street, San Francisco, CA 94103-1741, USA

Wiley-VCH Verlag GmbH, Boschstr. 12, D-69469 Weinheim, Germany

John Wiley & Sons Australia Ltd, 33 Park Road, Milton, Queensland 4064, Australia

John Wiley & Sons (Asia) Pte Ltd, 2 Clementi Loop #02-01, Jin Xing Distripark, Singapore 129809

John Wiley & Sons Canada Ltd, 22 Worcester Road, Etobicoke, Ontario, Canada M9W 1L1

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Library of Congress Cataloging-in-Publication Data

Software defined radio : architectures, systems, and functions / [edited by] Markus Dillinger, Kambiz Madani, Nancy Alonistioti.
p. cm. – (Wiley series in software radio)
Includes bibliographical references and index.
ISBN 0-470-85164-3 (alk. paper)
1. Software radio. I. Dillinger, Markus. II. Madani, Kambiz. III. Alonistioti, Nancy. IV. Series.

TK5103.4875.S57 2003
621.384 – dc21

2003043063

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

ISBN 0-470-85164-3

Typeset in 10/12pt Times by Laserwords Private Limited, Chennai, India
Printed and bound in Great Britain by Biddles Ltd, Guildford and King's Lynn
This book is printed on acid-free paper responsibly manufactured from sustainable forestry in which at least two trees are planted for each one used for paper production.

Contents

Preface

It is not uncommon for breakthrough concepts in wireless communications to take a considerable time to mature and gain momentum. In this respect, Software Defined Radio (SDR) is no exception, evolving very slowly from its military origin. J. Mitola first defined the area and also coined the term back in 1991 while Steinbrecher made initial investigations on the suitability of Software Radio in implementing multi-standard, flexible, smart base stations. As J. Mitola pointed out in his keynote speech at the 1st European Workshop on Software Radio in May 1997 when he referred to the slow start of SDR in the United States: ... *it was not that the technology was not within reach, but rather the fact that commercial applications are quite cost sensitive*. A renewal of interest in the area occurred around 1996 driven by two events, namely the creation of the Modular Multifunction Information Transfer System (MMITS) Forum[1] in March 1996, and the launch of the first European research project on SDR in the context of the Advanced Communications Technologies and Services (ACTS) programme of European Union (EU) funded research and development (R&D).

One could say that the title of the first European research project in this area was prophetic as very becomingly it was entitled FIRST (Flexible Integrated Radio Systems Technology). Observing the rising interest by the international research community in what was still known at that time as S/W radio technologies, the European Commission (EC) organised the 1st European Workshop on Software Radio in May 1997. The objective of this event was twofold. First it provided an excellent opportunity to assess the interest of the European research community in this area while at the same time it aimed to provide valuable feedback that would assist in shaping future research activities in this area.

Without doubt the 1st European Workshop on Software Radio was a major success. The attendance of more than 170 researchers representing academic and industrial centres not only from Europe, clearly showed that European industry was ready to invest in this challenging new area. This was reflected in the 3rd Call for Proposals of the ACTS R&D programme which called for proposals on '... novel technological work in S/W Radio technologies'. As a result of this call, two projects were launched in this area: Smart Universal Beam-forming (SUNBEAM) and Software Radio Technology (SORT), the first addressing the integration of smart array antennas in a 'software radio base station', while the second investigated intermediate frequency (IF) and baseband issues.

The follow-up of the very successful 1997 workshop took place in the summer of 1998, this time jointly organised by the EC and the MMITS Forum. The objective of the 2nd

[1] In December 1998 the MMITS Forum decided to change its name to the SDR (Software Defined Radio) Forum.

Workshop on Software Radio was to foster the exchange of experience in the field and explicitly to promote a broader approach, extending beyond the terminal. However, the most significant moment in this chronology of events was probably March 1999 when the three ACTS research projects active in this area took upon themselves the initiative to organise the First European Colloquium on Reconfigurable Radio Systems and Networks (RRSN). For the first time in the context of that event a different system-oriented and all-encompassing perspective/approach to SDR was put forward that went beyond the mainstream thinking in the area that was viewed SDR as a technology 'restricted' to the baseband and radio frequency (RF) functions of a wireless terminal.

This system-oriented point of view of SDR became the starting point for the 1st Call for Proposals of the IST (Information Society Technologies) R&D programme launched early in 2000. As we are now approaching the end of the IST programme we can safely claim that the projects performing work in the area of SDR have made considerable progress in the direction of the above-mentioned vision. This is manifested by the large number of contributions made to the SDR Forum as well as ITU Working Party (WP) 8F, which is in charge of defining the technical, operational, and spectrum issues related to the future development of IMT-2000 and systems beyond IMT-2000. The purpose of this book is to provide an integrated view of the work performed in this area in the context of the IST programme. In this light, the network functions for managing flexible devices and network elements are presented without ignoring at the same time the users' requirements and expectations from reconfigurable systems reflecting the system-oriented and all-encompassing perspective of the IST programme.

As we approach the end of the IST programme, this book acts as a repository of the ideas and concepts developed and investigated by the projects active in the area of RRSN. Without doubt reconfigurability will continue to play a central role in the overall system concept of wireless systems beyond 3G and also in the context of the 6th Framework Programme of EU funded R&D. In this context, the high-level objectives for the research work to be performed in the next four years could be summarised as follows:

- to achieve wide acceptance at standardisation level especially in what concerns network and service aspects; and
- to obtain to a clear understanding of the regulatory implications;

In this light, work in the context of the 6th Framework Programme will certainly build upon the sound basis established by the IST programme.

In conclusion, we wish to thank our colleagues who participated in the IST projects in the area of wireless communications for their commitment and co-operative spirit that is best reflected in this book. In particular, we thank the editors, Nancy Alonistioti, Markus Dillinger and Kambiz Madani, for their high quality contributions and Parbhu Patel for his enthusiasm and continuous support.

Brussels, 20 November, 2002
Dr Demosthenes Ikonomou
European Commission
DG Information Society

Abbreviations

2G	Second Generation Mobile Network
3GPP	Third Generation Partnership Project
AA	Alternating MAC Frame Utilisation Algorithm
AAA	Authentication, Authorisation and Accounting
AAAARCH	Authorisation, Authentication and Accounting ARCHitecture research group
ACH	Access feedback Channel
ADC	Analogue to Digital Converter
AF	Alternating Factor
AMM	Alternative Mode Monitoring
ANAI	Access Network Added Intelligence
ANFR	Council of the National Frequency Agency
AP	Access Point
APC	Access Point Controller
API	Application Programming Interface
ARIB	Association of Radio Industries and Business
ARQ	Automatic Repeat Request
AS	Application Server
ASIC	Application-specific Integrated Circuit
ASP	Application Services Provider
ATM	Asynchronous Transfer Mode
BCCH	Broadcast Control Channel
BCH	Broadcast Channel
BGCF	Breakout Gateway Control Function
BER	Bit Error Rate
BOV	Book of Vision
BPC	Baseband Processing Cells
BS	Base Station
BSC	Base Station Controller
BST	Base Station Transmitter
CAB	Charging, Accounting and Billing
CAC	Call Admission Control
CAMEL	Customised Applications for Mobile Network Enhanced Logic
CAP	CAMEL Application Part
CAST	Configurable Radio with Advanced Software Technology

CCF	Charging Collection Function
CDF	Cumulative Density Function
CDMA	Code Division Multiple Access
CDR	Charging Data Record
CEPT	Conference Européen des administration des Postes et des Télécommunications
CERP	Comité Européen des Régulateurs Postaux
CGF	Charging Gateway Function
CORBA	Common Object Request Broker Architecture
COPS	Common Open Policy Service protocol
COPS-PR	Common Open Policy protocol for Policy Provisioning
CPU	Central Processing Unit
CN	Core Network
CMM	Configuration Management Module
CSD	Circuit Switched Data
CSEL	Cell Selection
DCA	Dynamic Channel Allocation
DCH	Data Channel
DES	Discrete Event System
DHCP	Dynamic Host Configuration Protocol
DL	Downlink
DLC	Data Link Control
DLCC	DLC Connection
Drive	Dynamic Radio for IP-services in vehicular environments
DSA	Dynamic Spectrum Allocation
DSM	Distributed Shared Memory
DSP	Digital Signal Processor
DTX	Discontinues Transmission
DVB	Digital Video Broadcasting
DVB-T	Digital Video Broadcasting – Terrestrial
ECC	Electronic Communications Committee
ECTRA	European Committee for Regulatory Telecommunications Affairs
ED	Event Driven
EDGE	Enhanced Date Rate for GSM Evolution
ERC	European Radio Communications Committee
ETNO	European Telecommunications Network Operators' Association
ETO	European Telecommunication Office
ETSI	European Telecommunications Standards Institute
EXP	EXport Protocol
FA	False Alarm
FCA	Fixed Channel Allocation
FCC	Federal Communications Commission
FCCH	Frame Control Channel
FCFS	First Come First Serve
FCH	Frame Channel
FDD	Frequency Division Duplex

FEC	Forward Error Correction
FER	Frame Error Rate
FIFO	Fast in First Out
FPGA	Field Programmable Gate Array
FSA	Flexible Spectrum Allocation
FSM	Finite State Machine
FTAM	File Transfer, Access and Management
FTP	File Transfer Protocol
GGSN	Gateway GPRS Support Node
GIRC	Global Intelligent Reconfiguration Component
GMSC	Gateway Mobile Switching Centre
GoS	Grade of Service
GPS	Generic Process Sharing
GPRS	General Packet Radio Service
GRSF	Gateway Reconfiguration Support Function
GSM	Global System for Mobile Communications
GTP	Generic Tunnelling Protocol
GUI	Graphical User Interface
HAVi	Home Audio Video Interoperability
HCA	Hybrid Channel Allocation
HIPERLAN/2	High Performance Radio Local Area Network Type 2
HLR	Home Location Register
HO	Handover
HRM	Home Reconfiguration Manager
HSCSD	High Speed Circuit Switched Data
HSS	Home Subscriber Server
HTML	Hypersett Markup Language
HTTP	Hypersett Transfer Protocol
I-CSCF	Interrogating – Call Session Control Function
ID	Identification
IDL	Interface Definition Language
IEICE	Institute of Electronics, Information and Communications Engineers
IETF	Internet Engineering Task Force
IMEI	International Mobile Equipment Identity
IMS	IP Multimedia Subsystem
IMI	Initial Mode Identification
IMT-2000	International Mobile Telephony (3rd generation networks are referred as IMT-2000 within ITU)
INAP	Intelligent Network Application
I/O	Input/Output
IP	Internet Protocol
IRAC	Inter-Department Radio Advisory Committee
ISP	Internet Service Provider
IST	Information Society Technologies
IT	Information Technology
ITU	International Telecommunication Union

IU	Traffic User Interface
JAIN	Java APIs for Integrated Networks
JCC	Java Call Control
JCAC	Joint Call Admission Control
JOCAC	Joint Call Admission Control
JOLDC	Joint Load Control
JOSAC	Joint Session Admission Control
JOSCH	Joint Resource Scheduler
JRRM	Joint Radio Resource Management
JVM	Java Virtual Machine
LAN	Local Area Network
LCH	Long Transport Channel
LCS	Location Services
LCLS	Last Come Last Served
LFFS	Last Finished First Served
LHP	Last Hop Protocol
LIFO	Last in First Out
LIM	Location Information Manager
LODCL	Load Control
MAC	Medium Access Control
MAP	Mobile Application Part
mAh	milli Ampere hour
MD	Metering Device
MDC	Metering Devices Controller
MExE	Mobile Execution Environment
MGCF	Media Gateway Control Function
MIMM	Mode Identification and Monitoring Module
MM	Mobility Management
MMI	Man–Machine Interface
MNSM	Mode Negotiation and Switching Module
MO	Mobile Operator
MOBIVAS	Downloadable Mobile Value Added Services through Software Radio and Switching Integrated Platforms
MPHPT	Ministry of Public Management, Home Affairs, Posts and Telecommunications
MRFC	Multimedia Resource Function Controller
MSC	Mobile Switching Centre
MT	Mobile Terminal
MTS	Mobile Terminal Software
NTIA	National Telecommunications and Information Administration
NPRM	Notice of Proposed Rulemaking
OC	Occupied Carrier
OLAP	Online Analytical Processing
OMG	Object Management Group
ONS	Open Network Services
OSGi	Open Services Gateway initiative

OSM	Office of Spectrum Management
OSA	Open Service Access
OSI	Open Systems Interconnection
OTA	Over The Air
Overdrive	Over Dynamic multi Radio networks in Vehicular Environments
P2P	Peer to Peer
PCCPCH	Physical Common Control Channel
PCI	Personal Computer Interface
P-CSCF	Proxy-Call Session Control Function
PDA	Personal Digital Assistant
PDM	Packaging and Downloading Module
PDP	Policy Decision Point
PDU	Protocol Data Unit
PEP	Policy Enforcement Point
PHY	Physical Layer
PLC	Physical Layer Controller
PLMN	Public Land Mobile Network
PN	Pseudo Noise
PPP	Point-to-Point Protocol
PRM	Proxy Reconfigurable Manager
PS	Packet Switched
PW	Priority Weight
PV	Priority Vector
PVI	Priority Vector Information
QoS	Quality of Service
R&TTE	Radio Equipment and Telecommunications Terminal Equipment
RACH	Random Access Channel
RAN	Radio Access Network
ReSoA	Remote Socket Architecture
RAT	Radio Access Technology
RBB	Reconfigurable Baseband
RCH	Random Channel
RCM	Reconfiguration Manager
RDF	Resource Description Framework
RegTP	Regulierungsbehörde für Telekommunikation und Post
RESAC	Regular Traffic Session Admission Control
RF	Radio Frequency
RLC	Radio Link Control
RMM	Reconfigurable Baseband Management Module
RMSPP	Reconfiguration Management and Service Provision Platform
RNC	Radio Network Controller
RR	Round Robin
RRM	Radio Resource Management
RRN	Reconfigurable Radio Network
RRSF	RAN Reconfiguration Support Function
RRU	Radio Resource Unit

RS	Resource Scheduling
RSC	Resource Controller
RSCPM	Reconfiguration Control and Service Provision Manager
RSF	Reconfiguration Support Functions
RT	Real Time
SAC	Session Admission Control
SADL	Service Architecture Definition Language
SCF	Service Capabilities Features
SCH	Short Transport Channel
S-CSCF	Serving – Call Session Control Function
SCOUT	Smart ser-Centric cOmmUnication environmenT
SDL	Specification and Description Language
SDR	Software Defined Radio
SDSAC	Software Download Session Admission Control
SDM	Service Deployment Manager
SDU	Service Data Unit
SF	Spreading Factor
SGSN	Service GPRS Support Node
SHO	Soft Handover
SIP	Session Initiation Protocol
SIR	Signal to Interference Ratio
SP&P	Spectrum Plans and Policies
SME	Small and Medium Enterprise
S-MSC	Mobile Switching Center Server
SMS	Short Message Service
SOAP	Simple Object Access
SRM	Serving Reconfiguration Manager
SRSF	Serving Reconfiguration Support Function
SS7	Signalling System No. 7
SSA	Static Spectrum Allocation
SWR	Software Radio
TAP	Transferred Account Procedure
TCAP	Transaction Capabilities Application Protocol
TCP	Transmission Control Protocol
TCAM	Telecommunications Conformity Assessment and Market Surveillance Committee
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TELEC	Telecom Engineering Centre
TGS	TCAM Group on SDR
TREST	Traffic Estimation
TRSCH	Traffic Scheduler
TRSF	Terminal Reconfiguration Support Function
TRUST	Transparently Reconfigurable Ubiquitous Terminal
TTI	Transmission Time Interval
UDCH	User Data Channel

UE	User Equipment
UIMM	User Interaction Management Module
UL	Uplink
UML	Unified Markup Language
UMTS	Universal Mobile Telecommunications System
UPnP	Universal Plug and Play
UTRA	UMTS Terrestrial Radio Access
UTRAN	Ultra Terrestrial Radio Access Network
VAS	Value-Added Service Provider
VASM	Value-Added Service Manager
VASP	Value-Added Service Provider
VC	Void Carrier
VHE	Virtual Home Environment
VoIP	Voice over IP
VSM	Viable Systems Model
WAP	Wireless Access Protocol
WCDMA	Wideband Code Division Multiple Access
WLAN	Wireless Local Area Network
WML	Wireless Markup Language
WSDL	Web Service Definition Language
WTB	Wireless Telecommunications Bureau
XML	Extensible Markup Language

Contributors' Biographies

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Markus Dillinger received his Diplom-Ing. degree in telecommunications in 1990 from the University of Kaiserslautern, Germany. In 1991 he joined the Mobile Network Division at Siemens to develop call processing software for the GSM base stations. Later, he joined the system engineering division where he was responsible for the evaluation software for the Siemens Channel Sounder measurement equipment. In addition, he was responsible for the definition of the technical requirements and specification on the GSM base station line interfaces. From 1995 on he was working on the definition of the third mobile radio generation in the European research project FRAMES and in 1999 he was appointed Technical Manager of FRAMES. Since January 2000 he has been the project leader of the European research project TRUST and the follow-up project SCOUT for Software Radio. He has published many articles in the field of WCDMA and software radio.

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Genevieve Conaty is a human factors researcher at Motorola Labs in Basingstoke, England. Genevieve's work includes gathering information about user needs for future wireless applications, using a variety of methods such as consettual inquiry and group interviewing. Her work also involves the design, prototyping, and evaluation of new multimedia user interfaces. She completed her first degree in mathematical and computational science with a special interest in the history and philosophy of science at Stanford University. Her masters degree in human–computer interaction at Carnegie Mellon University included a team project about the design of wearable devices for teenagers. In addition, she worked on speech interfaces for information systems and games as part of the ICIE/RHINO Labs.

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Péter Kacsuk is the Head of the Laboratory of the Parallel and Distributed Systems in the Computer and Automation Research Institute of the Hungarian Academy of Sciences. He received his MSc and doctorate degrees from the Technical University of Budapest in 1976 and 1984, respectively. He received the kandidat degree from the Hungarian Academy in 1989. He habilitated at the University of Vienna in 1997 where he is a private professor. He is a part-time, full professor at the University of Westminster, the Eotvos Lorand Science University of Budapest and the University of Miskolc. He served as visiting scientist or professor several times at various universities of Austria, England, Germany, Spain, Australia and Japan. He has published two books, two lecture notes and more than 140 scientific papers on cluster and grid tools, mobile computing, parallel computer architectures, parallel software engineering and parallel logic programming.

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David Lund has worked as Senior R&D engineer with HW Communications Ltd for 5 years where his major responsibility guides the technical direction of their reconfigurable digital signal processing (RDSP) group. With a substantial track record in digital signal processing for communication applications, the group currently provides a major technical contribution to the 'Configurable Radio with Advanced Software Technologies' (CAST) project and the 'Two Dimensional Optical Storage' (TWODOS) project. CAST and TWODOS are both European Commission funded projects. CAST investigates the intelligent reconfiguration of SDR based mobile networks. TWODOS provides advanced optical storage research using SDR physical layer techniques for algorithm evaluation. David's recent PhD thesis entitled 'Reconfigurable Channel Coding for Future Communication Systems' tackles the problems associated with the practical implementation of information theoretical aspects of SDR.

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