J Sign Process Syst (2012) 69:1–3
DOI 10.1007/s11265-011-0651-5

Software Defined Radio—Guest Editorial

Friedrich K. Jondral · Jens Elsner · Michael Schwall

Received: 23 November 2011 / Revised: 23 November 2011 / Accepted: 23 November 2011 / Published online: 13 January 2012

Cognitive Radio (CR) is under intensive investigation since Joseph Mitola III published his doctoral dissertation[1] in 2000. It is common understanding that Software Defined Radio (SDR) is the enabling technology for CR. A CR is an SDR that additionally senses its environment, tracks changes, and reacts upon its findings. A CR is an autonomous unit in a communications environment that frequently exchanges information with the networks it is able to access as well as with other CR.

The main focus of CR publications since 2005 is on Dynamic Spectrum Access (DSA). Here CR is described as a means for the enhancement of efficiency in spectrum utilization, i.e. a means to combat under-utilization of spectrum. Exactly this subject is discussed by William Webb in his invited paper *Dynamic Spectrum Access is the Solution: What's the Problem?* to this special issue. First of all, he argues that spectrum sensing is not viable by hand held low-cost consumer terminals, "DSA devices will not be able to rely on sensing alone". He shows that geolocation is a promising alternative approach. Moreover, the change from sensing to geolocation tends to favor networked applications. In answering the question what the problem is to which DSA is the solution, Webb underlines the importance "to divorce DSA from cognitive radio and SDR". His conclusion is that DSA is useful for narrow bandwidth network-based applications and he offers machine-to-machine communication as the most obvious example.

We have arranged the ten regular papers that are introduced below into four categories. The first category contains four contributions.

1 SDR Waveform Development and Implementation

Due to their broad range of capabilities, Unmanned Ground Vehicles (UGV) and Unmanned Air Vehicles (UAV) have become important devices for civil and military applications. Since the operation area of UGVs covers rough and hilly terrain, establishing a line-of-sight data link to a ground control station is often impossible. The paper *SDR OFDM Waveform Design for a UGV/UAV Communication Scenario* by Christian Blümm, Christoph Heller, and Robert Weigel presents a specially designed OFDM-based waveform that helps to extend the operation area of a UGV by using a UAV as relay. Besides baseband processing, the authors describe the software defined hardware platform used in all stations and highlight the waveform's runtime flexibility. The tests reported show promising results.

A Cross-Layer Adaptive Modulation and Coding Scheme for Energy Efficient Software Defined Radio by Ying Chen and Linda M. Davis introduces a simple and innovative cross-layer Adaptive Modulation and Coding (AMC) scheme. A framework for energy-efficient cross-layer AMC that captures the impact of the MAC as well as of the PHY layer parameters on the AMC switching criteria is proposed. Cross-layer designs, naturally suited to SDR applications, can optimize the performance of the radio either for a fixed configuration or adaptively. The authors demonstrate their AMC scheme through examples of WLAN PHY layer and frequency domain equalized systems.

[1] Joseph Mitola III: *Cognitive Radio—An Integrated Agent Architecture for Software Defined Radio*. Ph.D. Dissertation, Department of Teleinformatics, KTH Stockholm (Sweden), 2000

F. K. Jondral · J. Elsner · M. Schwall (✉)
Karlsruhe Institute of Technology,
Karlsruhe, Germany
e-mail: michael.schwall@kit.edu

F. K. Jondral
e-mail: friedrich.jondral@kit.edu

J. Elsner
e-mail: jens.elsner@kit.edu

With their contribution *Sample Clock Offset Detection and Correction in the LTE Downlink*, Elliot Briggs, Brian Nutter, and Dan McLane present a method to jointly estimate and correct a sampling frequency mismatch in an LTE downlink scenario. Due to the narrow subcarrier spacing and wide bandwidth, especially this OFDM link is prone to a sample clock offset between transmitter and receiver. Already small amounts of mismatches cause a signal to noise ratio degradation due to the emerging inter-carrier interference. The proposed method is based on information already known to the receiver and allows clocks with lower precision to be employed in an LTE system. Besides MATLAB simulations, the authors also provide results for a fixed-point FPGA implementation.

The paper entitled *Implementations of Sorted-QR Decomposition for MIMO Receivers: Complexity, Reusability and Efficiency Analysis* by Venkatesh Ramakrishnan, Tobias Veerkamp, Gerd Ascheid, Marc Adrat, and Markus Antweiler deals with implementation issues arising in MIMO systems such as LTE. In a case study, different matrix decomposition algorithm implementations with varying degrees of flexibility and efficiency are compared.

2 SDR Algorithm Parallelization and Optimization

The next two articles deal with the optimization of waveform implementations using state of the art digital signal processors. The contributions describe the integration into existing waveform development environments and highlight the processing improvements.

Current developments in wireless communication systems, especially the rising data rates and multi user capabilities, have led to a tremendous increase of the transmitter and receiver complexity. Whereas traditional radios cope with these processing demands using application specific circuits, SDR still needs to support various standards and hence must be programmable.

With their contribution *Integration of GPU computing in a Software Radio environment*, Pierre-Henri Horrein, Christine Hennebert, and Frédéric Pétrot propose the employment of Graphics Processing Units (GPUs) to provide the required processing power and programmability. The article describes how to integrate the GPU processing into GNU Radio using Open Computing Language (OpenCL) and highlights the performance improvements.

In order to make use of the entire processing power of a multi-core General Purpose Processor (GPP) and hence to avoid system inefficiency, our paper, entitled *Code Parallelization for Multi-Core Software Defined Radio Platforms with OpenMP* provides an approach to parallelize C/C++ code using OpenMP. Besides the integration of OpenMP into an existing model-based waveform design framework, we present benchmark results for some reference implementations on a quad-core GPP and highlight the performance limitations of the parallelization.

3 SDR Reconfiguration

Reconfiguration is one of an SDR's key features. Two articles in this section cover this topic and present different approaches.

In Virtex-5 devices, the Digital Clock Managers (DCMs) include Dynamically Reconfigurable Ports (DRPs) that allow the operating clock frequency to be changed during runtime. Partial Reconfiguration (PR) is a method to time-share a portion of an FPGA while the rest of the device continues to operate unaffected. The contribution of Ke He, Louise Crockett, and Robert Stewart, entitled *Dynamic Reconfiguration Technologies Based on FPGA in Software Defined Radio System* presents a novel architecture that combines Dynamic Reconfigurable Port (DRP) with PR technology. It is demonstrated that this architecture reduces hardware utilization significantly compared with standard FPGA design.

The paper *Seamless Dynamic Runtime Reconfiguration in a Software Defined Radio* by Michael Dickens, J. Nicholas Laneman, and Brian P. Dunn proposes a system that allows for dynamic insertion and removal of entire waveforms, individual constituent blocks, and block algorithm implementations tailored to specific processors. This system performs reconfiguration while maintaining processing state, seamlessly without interrupting data processing, and with only the resources necessary for the given waveform and processors.

4 Miscellaneous Topics

In this final section, two articles that are not directly concerned with SDR, but with overall network system optimization and overall network efficiency are presented.

The article *Comparison of Cell Sizes for Cost Efficient Deployment of a Sensor Network Aided Cognitive Radio System* by Pål Grønsund and Ole Grøndalen gives insights into the required cell sizes for overlay networks. A sophisticated simulation model is used that allows evaluating the impact on both primary and opportunistic secondary modified WiMAX systems, a possible future application given the increasingly flexible spectrum usage policies.

Energy Efficieny of Heterogeneous Networks in LTE-Advanced is the title of the last featured paper, authored by Chadi Khirallah and John Thompson. It is concerned with the possible energy reductions in cellular networks when employing a) relays and b) adaptive energy saving by switching off unused base stations, a topic of great interest given the significant amount of electrical energy spent on communication. The model used is based on path loss approximations; it is simple but allows estimating the overall energy consumption in modern networks.

Enjoy reading!

Karlsruhe, November 2011
Jens Elsner
Friedrich K. Jondral
Michael Schwall

Friedrich K. Jondral received a Diploma in mathematics and a Doctoral degree in natural sciences (Dr.rer.nat.) from the Technische Universität Braunschweig (Germany) in 1975 and 1979, respectively. During the winter semester 1977/78 he was a visiting researcher to the Department of Mathematics, Nagoya University (Japan). From 1979 to 1992 Dr. Jondral was an employee of AEG-Telefunken (now Cassidian Electronics), Ulm (Germany), where he held various research, development and management positions. During this period he also lectured on applied mathematics at the Universität Ulm where he was appointed Adjunct Professor in 1991. Since 1993 Dr. Jondral has been Full Professor and Director of the Communications Engineering Lab (CEL) at the Karlsruhe Institute of Technology (KIT), the merger of the Universität Karlsruhe (TH) and the Forschungszentrum Karlsruhe. Here, from 2000 to 2002, he served as the Dean of the Department of Electrical Engineering and Information Technology. During a sabbatical in the summer semester 2004, Dr. Jondral was a visiting faculty to the Mobile and Portable Radio Research Group of Virginia Tech, Blacksburg (VA). His current research interests are in the fields of ultra wideband communications, software defined and cognitive radio, signal analysis, pattern recognition, network capacity optimization and dynamic spectrum allocation.

Jens Elsner is a research associate at the Communications Engineering Lab of the Karlsruhe Institute of Technology, Karlsruhe, Germany. His research interests include spectrum regulation, frequency agile ad hoc networks and software defined radio.

Michael Schwall is a PhD student at the Communications Engineering Lab (CEL), Karlsruhe Institute of Technology (KIT), Germany. He received his Diploma in Electrical and Communication Engineering from the University of Karlsruhe in 2009. His research is mainly focused on Software Defined Radio and Model-based waveform design with respect to waveform portability.