Sensor Network aided Agile Spectrum Access through Low-Latency Multi-Band Communications

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***Abstract*— Dynamic spectrum access supported by a low-latency wireless sensor network for spectrum usage monitoring is demonstrated using OpenAirInterface platform. The platform performs secondary communications in bands detected as free, thanks to its multi-band capability. With respect to application scenarios, the main target is to address agile broadband public safety communications. Firstly, this demonstration will highlight the newest hardware platforms offered by OpenAirInterface comprising the ExpressMIMO baseband engine and the AgileRF front-end. The second aspect of the demonstration aims to highlight OpenAirInterface's performance evaluation methodology allowing for scalable emulated real-time deployment of radio networks on generic PC-based computers.**

Keywords—OpenAirInterface platform, agile spectrum access, low-latency, dynamic spectrum access, scalable emulation methodologies.

I. Overview

OpenAirInterface is an open-source hardware/software development platform in the area of digital radio communications. The activity makes use of broadband and spectrally agile hardware platforms, in addition to high-performance emulation software for generic PC computers. The OpenAirInterface initiative recently developed and open-source implementation MODEM implementation for the ExpressMIMO baseband engine and x86 PC targets. This implementation currently supports the following provides a standard-compliant LTE Rel-8 implementation of PHY and MAC for a subset of the specifications [1] [2].

The software-based platform currently aligns its air-interface development with the evolving LTE standard but provides extensions for mesh networking, particularly in the MAC and Layer 3 protocol stack, in addition to Layer 1 extensions for distributed network synchronization. It can be can be seen as a mock standard for experimenting with real-time radio resources which retains the salient features of a real radio system, without all the required mechanisms for large-scale network deployment. Networking with tens of nodes using two-way real-time communication in both cellular and mesh topologies has been demonstrated in the context of several collaborative projects. The aim is to study practical aspects in modern radio systems such as distributed/cooperative processing, distributed synchronization, interference coordination and cancelation, spectrum aggregation. OpenAirInterface features an open-source software modem written in C comprising physical and link layer functionalities for cellular and mesh network topologies. This software modem can be used either for extensive computer simulations using different channel models or it can be used for real-time operation with the available hardware. In the latter case, it is run under the control of the real-time application interface (RTAI) which is an extension of the Linux operating system.

OpenAirInterface provides a partial implementation of the Rel-8/9 3GPP LTE specifications, primarily related to the access stratum. Specifically we provide:

- One or two-antenna transceivers for PHY specifications 36-211/36-212/36-213 corresponding to transmission modes 1, 2 and 6. Modes 4 and 5 are imminent. Currently TD-LTE frame configurations are (partially) implemented as far as 36-213 is concerned.
- Rel-8 MAC layer (36-311), with partial support of random-access and control elements.
- Rel-9 RLC (36-321) UM and TM modes. AM is Rel-4 and will be upgraded eventually.

In addition, two different RRC implementations are available. RRC mesh (an ultra-light RRC) which is used for small network deployments and is not 3GPP compliant by any means. It can be used as a testbench for controlling/testing the lower layers. RRC cellular is a subset of 3GPP RRC but does not currently use ASN.1 encoding/decoding for messages. Two Linux network devices (nasdriver, nasmesh) are provided to interface the 3GPP stack to Linux. This is a non-3GPP network interconnect. There are plans to integrate OpenAirInterface with open-source 3GPP networking implementations.

II. Demonstration Description

This demonstration was developed and implemented as part of the the European FP7 collaborative project SENDORA (sensor network for dynamic and cognitive radio access) [3]. The purpose of this demonstration is twofold. Firstly, it will highlight the newest hardware platforms offered by OpenAirInterface comprising the ExpressMIMO baseband engine which can manage up to eight 20-MHz radio channels, and the AgileRF RF front-end used for synthesizing and processing 20MHz channels from 200MHz to 8GHz. To avoid regulatory issues, the presented demonstration will be limited to 15dBm transmission in ISM bands (433.9MHz, 2.45GHz and 5.8GHz) and multi-band RF sensing. A key aspect will be to show the capacity of the hardware to occupy spectral holes in ISM bands and perform sparse spectrum aggregation. At least three fully functional radio nodes with dual-band TDD operation will be showcased.

The second aspect of the demonstration aims to highlight OpenAirInterface's performance evaluation methodology allowing for scalable emulated real-time deployment of radio networks on generic PC-based computers. The methodology makes use of a combination of a full access-layer protocol stack used for rapidly-deployable public-safety networks with physical-layer abstraction methods providing computationally-efficient performance evaluation with real applications and traffic sources.

III. AgileRF Prototype and ExpressMIMO Baseband Engine

EURECOM will provide an SDR solution housing the OpenAirInterface LTE MODEM development. It is based on two HW modules (ExpressMIMO and AgileRF) interfaced with a standard PC as given by Fig. 1. In this section we will present the AgileRF radio subsystem and in the following we will present the ExpressMIMO Baseband Engine.

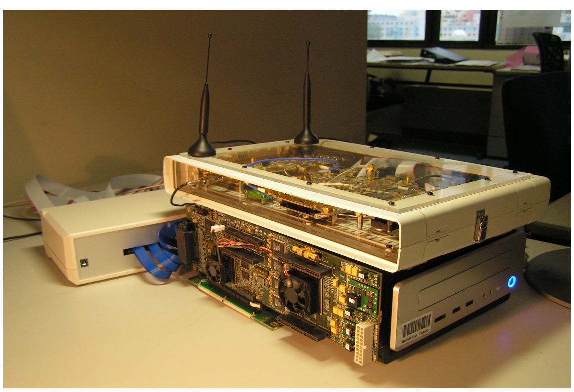

Fig. 1. AgileRF Prototype and ExpressMIMO Baseband Engine.

A. AgileRF Prototype

AgileRF is an RF front-end prototype for broadband radio-access. An example configuration is shown in Fig. 1 consisting of a single TDD transceiver operating over the 200MHz-8GHz frequency range. The AgileRF boards comprise the following subsystems:

1) RX: This is a generic broadband receiver board (200MHz-8GHz, 20MHz channels), Quadrature (I/Q) output.
2) TX: This is a generic quadrature transmitter board operating in the frequency range of 200MHz-8GHz.
3) Synth 1: 8.2GHz local oscillator (used for systems below 4GHz, e.g. DAB/DMB, LTE/GSM/WCDMA/HSPA).
4) Synth 2: 4-8GHz local oscillator.

The receiver is comprised of a broadband LNA followed by a band-selection filter network. A direct conversion quadrature mixer is used for inputs in the range 4-8GHz. An additional upconverter to 4-8GHz is used for input signals in the 200MHz-4GHz range. The band-selection filters and RF gain levels are controllable via a digital interface (controlled here by ExpressMIMO). Baseband outputs are provided via differential quadrature (I/Q) signals from the baseband engine. The baseband section has maximal baseband channel bandwidth of 20MHz and a sharp DC block for RF carrier leakage removal. Baseband amplifiers provide 60dB of gain, which when combined with variable RF attenuators allow for 70dB of gain control.

The transmitter has maximal baseband channel bandwidth of 20MHz. Baseband inputs are provided via differential quadrature (I/Q) signals from the baseband engine. Band-selection filters are provided to guarantee image-free outputs in all target bands. The bands are, DC-200MHz, 200-400MHz. 400-600MHz, 600-1000MHz, 1-2GHz, 2-3GHz, 3-5GHz, 5-8GHz.

B. ExpressMIMO Baseband Engine

ExpressMIMO is an 8-way signal processing engine comprising one Xilinx Virtex 5 LX110T embedded system (8xPCIexpress, 1Gbit/s Ethernet, SystemACE Flash, 128kByte DDR memory, LVDS expansion) and one Xilinx Virtex 5 LX330 computational engine (2Gbyte 64-bit DDR2 memory 4 AD9862 Mixed Signal Front-Ends, 1 AD9510 Precision PLL + VCO programmable clock source, Custom RF interface). It is powered by a standard 430W PC ATX power supply.

AirInterface applications are based on a software-radio description in C-language running on the ExpressMIMO embedded system and the host PC. C-language implementations currently being integrated on ExpressMIMO include wideband RF sensing, 802.11a/g/p PHY and release 8 3GPP/LTE. The demonstration will make use of an adapted LTE-PHY for rapidly-deployable networks and wideband RF sensing functionality in support of sparse spectrum aggregation.

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