Implementation of Reconfigurable Mobile Device with Licensed Shared Access Functionality

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Abstract— **Recently, as the heterogeneous network (HetNet) has been deployed widely to support various kinds of Radio Access Networks(RANs) with a combination of Macro, Pico, and/or Femto cells, research and standardization regarding the concept of Licensed Shared Access (LSA) for supporting spectrum sharing have been very actively performed. Especially, Working Group 1 (WG1) of Technical Committee (TC) Reconfigurable Radio System (RRS) of European Telecommunications Standards Institute (ETSI) has been a main driving force for developing a system requirements and use cases for the LSA system, while WG2 has set up a standard architecture of reconfigurable Mobile Device (MD) that can be applied to the LSA system. In this paper, we introduce the reconfigurable MD architecture for supporting LSA-based spectrum sharing. An implementation of a test-bed of reconfigurable MD is presented in order to verify the feasibility of the standard MD architecture for the purpose of LSA-based spectrum sharing through various experimental tests.**

I. INTRODUCTION

Recently, the need for spectral resources is explosively increasing as the use of smart phone increases tremendously. According to [1], global mobile traffic is expected to grow by 10-30 times within 10 years between 2010 and 2012, which will eventually result in a great shortage of the spectral resources.

Nowadays, the spectral resources are being used in accordance with a specific policy in each wireless communication network, meaning that each spectral resource is being used for a specific purpose pre-determined by the government. Consequently, some frequency bands are not very efficiently used [2,3], meaning that the spectrum is occupied without any use for a quite long time period. For instance, spectra such as Public Protection and Disaster Relief (PPDR) spectrum, etc. are not in use for most ordinary days while it is strictly prohibited to use it for any other radio applications (RAs) but for the original purpose itself. Consequently, the efficiency of spectral use becomes extremely low.

To cope with the explosively increasing mobile traffic and inefficient use of some spectral bands, researches and developments on the spectrum sharing have been very actively performed in many countries. Especially, in Europe, the technology of spectrum sharing using Licensed Shared Access (LSA) in 2.3-2.4GHz band has been performed. Presently, regulations and standardizations for the LSA-based spectrum sharing in 2.3-2.4GHz band to be proliferated very widely in European countries have been presented in the Conference of European Postal and Telecommunications administrations (CEPT) regulators [4] and TC-RRS of ETSI [5,6]. Meanwhile, WG2 of TC-RRS of ETSI has suggested a standard architecture of reconfigurable Mobile Device (MD) for realizing the CR and SDR technologies in practical communication systems [7].

In this paper, using a test-bed implemented for laboratory tests, we verify that the standard architecture of reconfigurable MD suggested by WG2 of TC-RRS of ETSI is suitable for the LSA-based spectrum sharing of which the scenario is demonstrated by WG1 of TC-RRS of ETSI.

The rest of this paper is organized as follows. In section II, the Reconfigurable MD is introduced. Section III shows the system implementation of reconfigurable MD test-bed. Section IV shows the experimental results and finally in section V a conclusion is presented.

II. RECONFIGURABLE MOBILE DEVICE

ETSI's TC RRS has developed a standard hardware platform architecture for a reconfigurable MD since 2011. In this section, a reference model of reconfigurable MD architecture for supporting spectrum sharing is introduced. The reference model is based on the standard architecture that defined in [7]. Note that the standardization of TC RRS is limited to the four entities of Communication Services Layer (CSL) and five entities of Radio Control Framework (RCF).

The CSL, which is a part of standard architecture, is a layer related to communication services supporting both generic applications such as Internet access and specific applications related to multiradio applications. A reconfigurable MD user can control and manage each Radio Application through these CSL components because each one can control and manage the RA through interacting with each component of the RCF. There are four entities included in the CSL, i.e., Administrator, Mobility Policy Manager (MPM), Networking stack and

Monitor. Each of these four entities has different responsibilities as follows. The Administrator can request installation or uninstallation of an RA, and can create or delete an RA instance. It also provides information about each RA and its status. The MPM monitors the radio environments and MD capabilities, requests activation or deactivation of RAs, and provides information about the RA list. It also selects among different RATs and discovers peer communication equipment and arrangement of associations. The Networking stack sends and receives user data. The Monitor transfers information from the RAs to the user or to the proper destination component of the MD.

RCF is a control framework that, as a part of the operating system (OS), extends its radio resource management capabilities. RCF provides processing instructions whereby the CSL can manage the RAs, and consists of five components: Configuration Manager, Radio Connection Manager, Flow Controller, Multiradio Controller and Resource Manager. The Configuration Manager provides for the installation and uninstallation of RAs and the creation and deletion of RA instances in the Radio OS; it also manages the radio parameters of the RAs and provides access to these parameters. The Radio Connection Manager provides for the activation and deactivation of RAs according to user requests, and provides overall management of user data flows, which can also be switched from one RA to another. The Flow Controller is responsible for sending and receiving user data packets, and controls the flow of signaling packets. The Multiradio Controller schedules requests for radio resources issued by concurrently executing RAs, and detects and manages any interoperability problems among concurrently executing RAs. The Resource Manager manages computational resources to share them among simultaneously active RAs and to guarantee their real-time requirements.

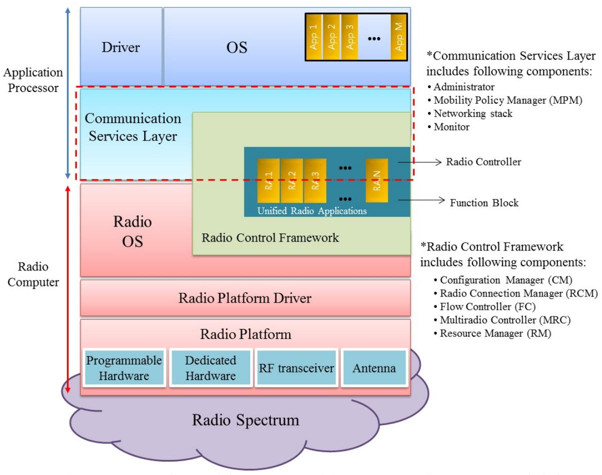

Fig. 1 Reconfigurable MD Architecture Reference Model for Multiradio Applications.

Fig. 1 exemplifies a reconfigurable MD architecture reference model for multiradio applications. As shown in the Fig. 1, the reconfigurable MD architecture shall include at least a Radio Computer. In the example of Fig. 1, the red-dotted part belongs to either Radio Computer or Application Processor depending on the specific implementation.

In the example of Fig. 1, the operation of Application Processor is performed by a given OS, which is preferably performed on non-real-time bases, whereas Radio Computer's operation is performed by another OS, which should support real-time operations of RAs. The OS of Radio Computer is referred to as Radio OS in this paper. Any appropriate OS empowered by RCF can be Radio OS[7]. In other words, reconfigurable MD architecture is independent of any OS or any platform because RCF accumulates all functionality related to radio reconfiguration.

The Application Processor in Fig. 1 includes the following components: (1)A Driver which has the purpose of activating the hardware devices (such as camera, speaker, etc.) on a given MD, (2)A non-real time OS for execution of Administrator, MPM, Networking stack and Monitor [7] which are part of the CSL as previously described, and (3)Radio Controller in RA for sending context information to the Monitor and Tx/Rx data to/from Networking stack.

Note that the driver included in Application Processor is to activate general hardware components such as camera, speaker, display, etc. It particularly means that the driver is completely irrelevant to the MD reconfiguration.

The Radio Computer includes the following components: (1)Radio OS, a real-time OS, for executing functional blocks of RA, (2)A radio platform driver which is a hardware driver for the Radio OS to interact with the radio platform hardware.

From Fig. 1, it can also be observed that the 5 entities of the RCF introduced earlier in this section are classified into two groups. One group relates to real-time execution and the other group to non-real-time execution as shown in Fig. 1. Which entities of Radio Control Framework relate to real-time and non-real-time execution, can be determined by each vendor.

III. System Implementation

In this section, implementation of a reconfigurable MD test-bed is presented. The implemented reconfigurable MD test-bed is compliant with the standard architecture released by ETSI TC-RRS [7].

As shown in Fig. 2, the test-bed system consists of two parts: one is a terminal computer for baseband and upper-layer signal processing; the other is a RF transceiver, i.e., the Ettus Universal Software Radio Peripheral N210 (USRP N210). These two parts are connected via gigabit Ethernet (GbE). The terminal computer is simply a personal computer (PC), including a central processing unit (CPU) and a graphic processing unit (GPU). The CPU executes the Administrator and MPM functions to provide control over entire system and to perform network selection, respectively; the GPU provides modem functionalities for the selected RA. Note that the Configuration Manager and Radio Connection Manager described in Section 2 are also implemented in the CPU such that these entities perform the configuration of reconfigurable

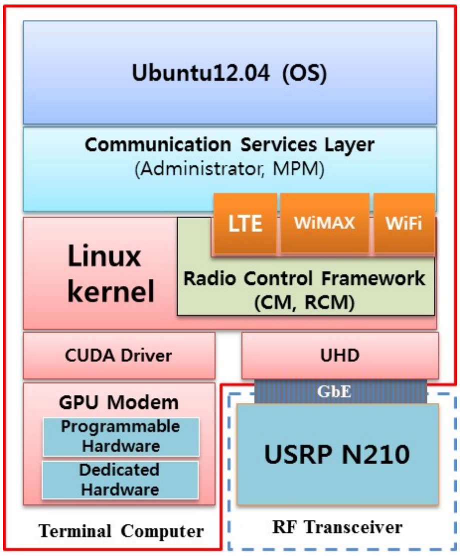

Fig. 2 Block diagram of implemented test-bed

MD and activation of RA according to the RA selection instructions of the MPM. It also implies that the Radio OS mentioned in the previous sections manages the GPU. The Linux kernel controls the GPU and USRP N210, which includes the field programmable gate array (FPGA), analog-to-digital convertor and digital-to-analog convertor, through a compute unified device architecture (CUDA) driver and USRP Hardware Driver (UHD), respectively. We have implemented multiple RA codes on this GPU-based reconfigurable MD. The superiorities of the GPU-based software modem have been previously demonstrated [8, 9]. Table 1 shows the parameters of RATs that are supported by our reconfigurable MD test-bed.

Table 1. Physical layer specifications of implemented RATs

	LTE	WiMAX	Wi-Fi
Waveform Standard	3GPP Rel. 10	IEEE 802.16e	IEEE 802.11g
Carrier Bandwidth (MHz)	10/20	5/10	20
Duplex Mode	FDD/TDD	TDD	TDD
Modulation	16QAM/ 64QAM	16QAM	64QAM
Data Rate (MAX.)	37Mbps	12Mbps	26Mbps

Fig. 3 is a photograph of the implemented reconfigurable MD test-bed. This test-bed is a hardware implementation of the block diagram depicted in Fig. 2, with the exception that a graphic user interface (GUI) and spectrum analyzer has been added to monitor the operation of the test-bed system. A general-purpose PC equipped with a GPU and CPU was used as the terminal computer, while a USRP N210 was used as the RF transceiver as mentioned earlier. Inside the terminal computer, the CPU and GPU can be observed. As mentioned above, these are respectively used as the controller and modem, and also respectively provide the functionalities of Administrator, MPM, Configuration Manager, and Radio Connection Manager. Through the GUI, image data are replayed, allowing verification of the functionality of the RF transceiver in USRP N210, as well as verification of the GPU's modem functionality.

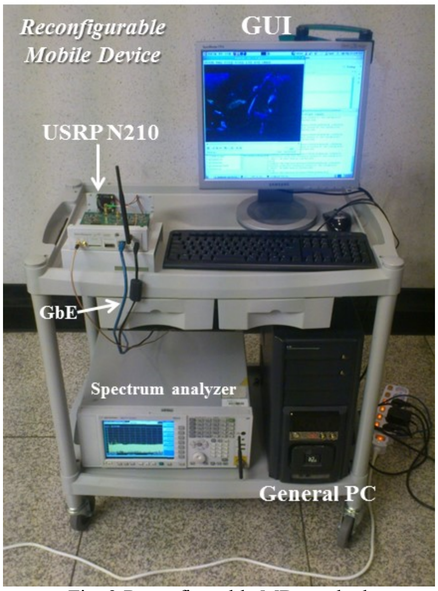

Fig. 3 Reconfigurable MD test-bed

IV. Experimental Results

In this section, it is verified that the test-bed implemented in Section 3 is applicable to the LSA-based spectrum sharing. As mentioned earlier, researches on the LSA technology is performed in WG1 of TC-RRS of ETSI presenting use cases for the LSA to be implemented in 2.3-2.4GHz band.

According to the use case introduced in "Bandwidth Expansion for Mobile Network Operator" [5], Mobile Station, i.e., MD, should be able to adaptively change some parameters such as operating frequency, transmission bandwidth, transmit power, and receiver sensitivity in accordance with the environmental request. In order to verify the applicability of the LSA-based spectrum sharing in our test-bed, we have followed the procedures suggested in the use case of WG1 of TC-RRS of ETSI.

Fig. 4 illustrates experimental results obtained as a result of MD reconfiguration. As shown in the upper dotted box, the configuration of the MD is set up as follows: operating frequency is 2.45GHz, bandwidth is 5MHz, transmit power is -46dBm, and receiver sensitivity is -90dBm.

Now, let's assume that the operating frequency is to be moved to 2.3-2.4GHz band. As described in Section 2, management of radio parameters of RA is performed by Configuration Manager that included in RCF. Administrator in CSL requests Configuration manager in RCF to change the related parameters appropriately. Note that, the parameter values in this paper, i.e., Operating frequency is 2.32GHz, bandwidth is 10MHz, transmit power is -40dBm, receiver sensitivity is -95dBm, is arbitrarily set up in that way, meaning that, in practical situations, the corresponding base station system using LSA will properly set up the parameters values accordingly.

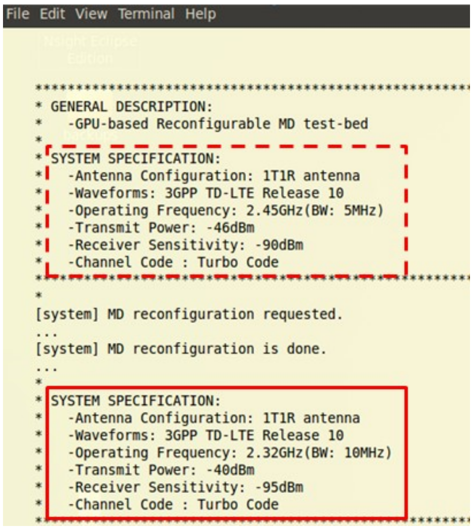

Fig. 4 Experimental results for MD reconfiguration

As shown in the lower dotted box, new parameters values have been set up in the target MD as requested and executed by Administrator and Configuration manager, respectively.

V. CONCLUSION

In this paper, we introduced a reconfigurable MD to perform the system parameter configuration such as operating frequency, transmission bandwidth, transmit power, and receiver sensitivity for the use case of LSA-based spectrum sharing [5]. In order to verify the functionality of MD configuration, we implemented a reconfigurable MD test-bed using a PC and USRP as a multiple RAT modem and RF Transceiver, respectively. In experiments using the reconfigurable MD test-bed, the parameters such as operating frequency, transmission bandwidth, transmit power, and receiver sensitivity are adjusted for the LSA-based spectrum sharing. The necessary parameters can be controlled systematically upon the request of the software entities defined in the standard architecture of the reconfigurable MD, i.e., Administrator in CSL and Configuration Manager in RCF. From the results obtained in the experimental tests using the implemented test-bed, we have verified that the reconfigurable MD defined in WG2 of TC-RRS of ETSI is capable of handling not only the CR and SDR technologies but also the LSA-based spectrum sharing.

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