Operation of Reconfigurable Mobile Device for Spectrum Sharing

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Abstract— **In order for a mobile device to efficiently support the spectrum sharing, the mobile device shall be reconfigurable, meaning that its radio application code has to be adaptively changed in accordance with the hopping of desired spectral band. Based on the standard architecture defined in Working Group (WG)2 of Technical Committee (TC) – Reconfigurable Radio System (RRS) of European Telecommunications Standards Institute (ETSI), this paper presents related procedures among the software entities of the reconfigurable mobile device required for implementing the spectrum sharing. In this paper, we consider the scenario of the spectrum sharing that has been demonstrated in WG1 of TC-RRS of ETSI. The related parameters such as center frequency, modulation scheme, etc considered in this paper are also based on what have been presented by the WG1 of TC-RRS. This paper also addresses the interactions among the standard software entities of the reconfigurable mobile device and required interfaces services.**

I. INTRODUCTION

Global mobile data traffic is expected to grow up to 24.3 exabytes per month by 2019, which is nearly a tenfold increase compared to the traffic in 2014 [1]. To cope with the explosive increase of the data traffic, various enabling technologies such as full dimension multi-input multi-output, device-to-device communication, new waveform design, etc have been researched very actively [2]. Especially, World Radiocommunication Conference in 2015 (WRC-15) of the International Telecommunication Union Radiocommunication sector (ITU-R) considers the technology of spectrum sharing as a key methodology that is applicable in 5th generation (5G) mobile communications [3]. It is, however, important that the spectrum sharing, i.e., a technology which allows plural communication systems operate simultaneously in the same frequency band, cannot stand alone without Cognitive Radio (CR) and Software Defined Radio (SDR), for which the standardization has very actively been performed in the Technical Committee (TC)-Reconfigurable Radio Systems (RRS) of European Telecommunications Standards Institute (ETSI) for the last decade. Among 4 Working Groups (WGs) in TC-RRS of ETSI, WG1 develop and maintain a common technical framework for SDR and CR systems standardization regarding system level aspects. In [4], WG1 has described various scenarios for the use case of the spectrum sharing through the procedure of Licensed Shared Access (LSA). Meanwhile, WG2 of TC-RRS of ETSI has developed a standard architecture and related interfaces for the SDR-related system. In [5], WG2 has released a standard architecture of reconfigurable Mobile Device (MD) with its main effort being focused on resolving the problem of portability between Radio Application (RA) code and radio platform. WG2 has also defined multi-radio interfaces for the reconfigurable MD, and information model and protocol for the radio frequency interfaces in [6] and [7], respectively.

The main contribution of this paper is to show how the reconfiguration of MD can be achieved for realizing the LSA-based spectrum sharing of which the scenario is demonstrated by WG1 of TC-RRS of ETSI in [4] while the target MD is compliant with the standard architecture released by WG2 of TC-RRS of ETSI [5]. In order to verify the reconfiguration of MD required for the LSA-based spectrum sharing, we specify what interactions should occur in what order among software entities in the reconfigurable MD of ETSI-standard architecture. The systematic interactions among software entities are referred to as "procedure" in this paper.

The rest of this paper is organized as follows. Section 2 introduces the standard architecture of reconfigurable MD developed by WG2 of TC-RRS, based on which the procedures are set up in the following section. Section 3 proposes the systematic procedures which specify the interactions among software entities of the ETSI-standard reconfigurable MD for the realization of the LSA-based spectrum sharing. Finally, Section 4 concludes this paper.

II. ARCHITECTURAL MODEL FOR RECONFIGURABLE MOBILE DEVICES

WG2 of TC-RRS of ETSI has developed a standard architecture of reconfigurable MD and related interfaces with an intention that any desired radio access technologies (RATs) can be realized in the reconfigurable MD by downloading the target RA code from a public domain, e.g., RadioApp Store, regardless of the hardware platform of the MD. This section introduces a brief summary of the standard architecture and related interfaces, based on which the systematic procedures are developed in the following section in such a way that the software entities in the reconfigurable MD interact with one another for implementing the LSA-based spectrum sharing.

A. Architecture for reconfigurable MD

Fig. 1 illustrates the reconfigurable MD architecture and related interfaces proposed by WG2 of TC-RRS of ETSI. As shown in the figure, the architecture consists of Communication Services Layer (CSL), Radio Control Framework (RCF), Unified Radio Applications (URA), and Radio Platform [5]. Although the 4 components are shown in the figure, the necessary part of ETSI standard includes the 4 entities in CSL, i.e., Administrator, Mobile Policy Manager (MPM), Networking stack, and Monitor, and 5 entities in RCF, i.e., Configuration Manager (CM), Radio Connection Manager (RCM), Flow Controller (FC), Multi-Radio Controller (MRC), and Resource Manager (RM), only, which means that Radio Platform is vendor-specific and URA is the downloaded RA code consisting of functional blocks, metadata and other software needed for the processing of context information [5]-[7].

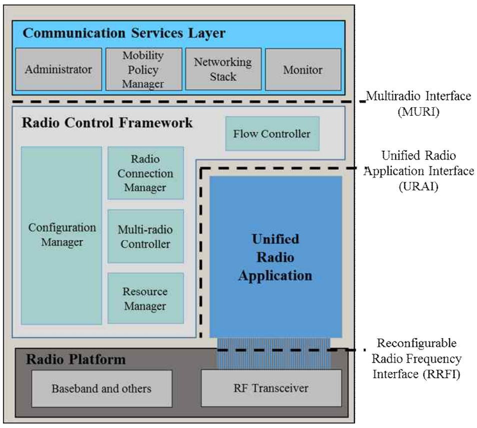

Fig. 1 Reconfigurable MD architecture and related interfaces

Functionality of each of 4 entities in CSL can be summarized as follows. Administrator entity requests (un)installation of URA and creates or deletes instances of URA. MPM entity monitors the radio environments and MD capabilities, requests (de)activation of URA, and provides information about the URA list. Networking stack entity sends and receives user data. Monitor entity transfers context information from URA to user or proper destination entity in MD.

Functionality of each of 5 entities in RCF can be summarized as follows. CM entity (un)installs, creates or deletes instances of URA and manages the access to the radio parameters of the URA. RCM entity (de)activates URA according to user requests, and manages user data flows. FC entity sends and receives user data packets and controls the flow of signaling packets. MRC entity schedules the requests for radio resources issued by concurrently executing URAs, and detects and manages the interoperability problems among the concurrently executed URAs. RM entity manages computational resources in order to share them among simultaneously active URA, and guarantees their real-time execution.

RA code, i.e., a software which enforces the generation of the transmit RF signals or the decoding of the received RF signals, becomes URA once it is downloaded into the reconfigurable MD. Since all RAs exhibit a common behavior from the reconfigurable MD perspective once they are downloaded in the reconfigurable MD, the downloaded RA code is called URA. As mentioned earlier, URA consists of functional blocks which exhibit the required modem functions of the corresponding RAT.

Radio Platform shown in Fig. 1 is part of MD hardware which relates to radio processing capability, including programmable components, hardware accelerators, RF transceiver, and antenna(s).

B. Interfaces for reconfigurable MD

As shown in Fig. 1, there are 3 kinds of interfaces, Multiradio Interface (MURI), Unified Radio Application Interface (URAI), and Reconfigurable RF Interface (RRFI), with which each entity of CSL, RCF, and Radio Platform can interact with one another.

MURI interfaces each entity of CSL and RCF with each other. It provides 3 kinds of services, i.e., administrative services, access control services, and data flow services [6]. URAI interfaces each entity of RCF and URA. It provides 5 kinds of services, i.e., RA management services, user data flow services, multiradio control services, resource management services, and parameter administration services [5]. RRFI interfaces URA and Radio Platform. It provides 5 kinds of services, i.e., spectrum control services, power control services, antenna management services, Transmit (Tx)/ Receive (Rx) chain control services, and radio virtual machine protection services [7].

III. PROPOSED PROCEDURES FOR SPECTRUM SHARING IN RECONFIGURABLE MD

In this section, we present procedures of spectrum sharing for the reconfigurable MD of which the architecture is specified as an ETSI standard as briefly summarized in the previous section. Each procedure introduced in this section specifies how the entities in CSL, RCF, and Radio Platform shown in Fig. 1 interact with one another while the URA is processed for the LSA-based spectrum sharing during Tx and/or Rx mode.

Fig. 2 illustrates a conceptual view of realizing the spectrum sharing using LSA, of which the basic scenario has been demonstrated by WG1 of TC-RRS of ETSI [4] as follows. LSA Repository shown in Fig. 2 contains a database of spatial and temporal information regarding the spectrum use of incumbent user. Based on the information provided from the LSA Repository, LSA Controller determines the availability of spectrum that can be shared using the LSA. In the case when the spectrum is available, the network management system, which is denoted as “Operation, Administration and

Maintenance (OAM)" in Fig. 2, acknowledges the availability of the spectrum to the corresponding base station.

Use case of expanding a bandwidth using LSA has been released by WG1 of TC-RRS of ETSI in [4], which is a basis of the spectrum sharing procedures introduced in this section. The use case can be summarized as follows. Let's consider a case that a network operator providing an LTE service wants to switch the spectral band from its own LTE band to the band of 2.3-2.4 GHz at a specific time. Assuming the network operator has held the individual authorization for using the extra band of 2.3-2.4 GHz, the LSA controller shown in Fig. 2 decides which base stations can be allowed to use the extra spectral band for the required time period. Receiving the information regarding the availability of the extra spectral band from the LSA controller, OAM shown in Fig. 2 notifies the availability of the spectrum those base stations which may use the extra spectral band of 2.3-2.4GHz. In order to implement the above-written use case, the following parameters have to be updated in each MD that operates in those base stations [4]: operating frequency, transmission bandwidth, transmit power, receiver sensitivity, and modulation scheme. Now, we introduce procedures during which the above-written 5 parameters are properly updated for the use of extra spectral band.

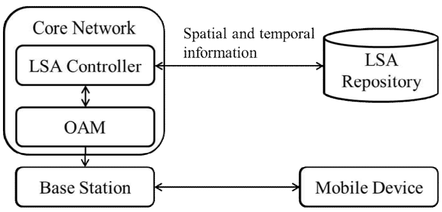

Fig. 2 Conceptual view of realizing spectrum sharing with LSA

A. Procedures for the reconfiguration of RF transceiver

Firstly, we propose a procedure for updating the 4 parameters, i.e., operating frequency, transmission bandwidth, transmit power, and receiver sensitivity, which are related to the functional changes in RF transceiver.

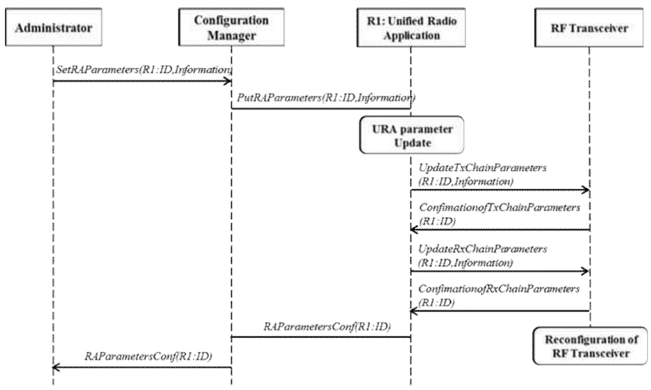

Fig. 3 RF Transceiver Reconfiguration procedure

Fig. 3 illustrates the procedure of updating the parameters for the functional changes in RF transceiver. The procedure shown in Fig. 3 can be summarized in 6 steps as shown below.

Step 1. Administrator in CSL sends a *SetRAParameters* signal which includes the operating frequency, transmission bandwidth, transmit power, and receiver sensitivity together with the RA identification (ID) to CM in RCF.

Step 2. Upon the request from CM, Radio Operating System (ROS) updates the parameters of designated URA. Note that ROS denotes any appropriate OS empowered by RCF, which is a real-time OS for executing functional blocks of URA [5].

Step 3. For Tx, URA sends RF transceiver an *UpdateTxChainParameters* signal which includes information of the RA ID and 4 parameters, and receives a confirmation from RF transceiver through a *ConfimationofTxChain-arameters* signal.

Step 4. For Rx, URA sends RF transceiver an *UpdateRxChainParameters* signal which includes information of the RA ID and 4 parameters, and receives a confirmation from RF transceiver through a *ConfimationofRxChain-arameters* signal.

Step 5. URA transfers CM an *RAParametersConf* signal through ROS, which means that the update of 4 parameters in RF transceiver has been completed.

Step 6. CM transfers Administrator an *RAParametersConf* signal to complete the procedure.

Reconfiguration of RF transceiver can be achieved through the procedure shown above, which updates the 4 parameters, i.e., operating frequency, transmission bandwidth, transmit power, and receiver sensitivity, related with the functional changes in RF transceiver. Note that Steps 1 and 6 make use of the administrative service of MURI [6], Steps 2 and 5 utilize the parameter administration service of URAI [5] and Steps 3 and 4 utilize the Tx/Rx chain control service [7].

B. Procedures for the reconfiguration of URA

Secondly, we propose a procedure for updating the modulation scheme, which is related to the functional changes in URA. The reconfiguration of URA can be performed by changing the functional blocks. The procedure of updating URA with new functional blocks introduced in this subsection is needed when the network operator decides to change and/or optimize the modulation scheme for the new spectrum of 2.3-2.4GHz band.

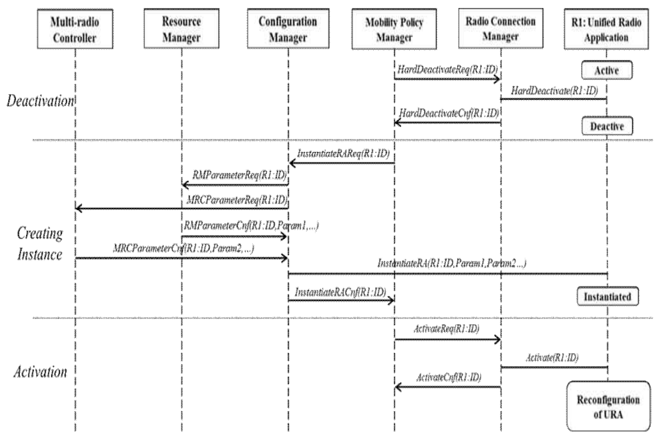

Fig. 4 URA Reconfiguration procedure

Fig. 4 illustrates the procedure of updating the parameter, i.e., modulation scheme, for the functional changes in URA. The procedure shown in Fig. 4 can be summarized in 12 steps as shown below.

Step 1. In order to deactivate the current URA, MPM transfers RCM *HardDeactivateReq* signal which includes the RA ID.

Step 2. Upon the request form RCM, ROS deactivates the designated URA.

Step 3. After ROS completes the hard deactivation of the URA, RCM acknowledges the completion of the deactivation procedure by sending an *HardDeactivateCnf* signal to MPM.

Step 4. In order to create an instance of a new URA, MPM transfers an *InstantiateRAReq* signal including the ID of the URA to be instantiated to CM.

Step 5. CM transfers an *RMParameterReq* signal and an *MRCParameterReq* signal including the ID of the URA in order to get the parameters needed for URA activation to RM and MRC.

Step 6. CM receives an *RMParameterCnf* signal including the ID of the URA and radio resource parameters from RM.

Step 7. CM receives an *MRCParameterCnf* signal including the ID of the URA and computational resource parameters from MRC.

Step 8. CM transfers URA ID and the received parameters for performing the URA instantiation to ROS.

Step 9. After creating an instance, CM transfers an *InstantiateRACnf* signal including URA ID to MPM.

Step 10. In order to activate the new URA, MPM transfers an *ActivateReq* signal including the ID of the URA to RCM.

Step 11. Upon request from RCM, ROS activates the designated URA.

Step 12. After ROS completes the activation of the URA, RCM sends back to MPM an *ActivateCnf* signal.

By updating the modulation scheme through the procedure shown above, the reconfiguration of URA can be achieved. Note that Steps 1, 3, 4, 9, 10 and 12 make use of the access control services of MURI [6], Steps 2 and 11 utilize the radio application management services of URAI [5] and Step 8 makes use of parameters administration services of URAI [5]. Meanwhile, Steps 5, 6, and 7 are related with the interactions among entities in RCF, which are consequently vendor-specific.

For the LSA-based spectrum sharing, it is necessary for RF transceiver and URA to be reconfigurable, meaning that the related parameters, i.e., operating frequency, transmission bandwidth, transmit power, receiver sensitivity, and modulation scheme, should be properly updated. Through the procedures introduced in this section, the 5 parameters can be changed in accordance with the requirements of the LSA-based spectrum sharing. It is noteworthy that the modulation-related parameters such as modulation, precoding, channel estimation, etc as well as the frequency-related parameters can all be adaptively optimized according to the new spectrum in a reconfigurable MD during the procedures of spectrum sharing.

IV. CONCLUSION

WG1 of TC-RRS of ETSI specified what parameters should be updated during the LSA-based spectrum sharing, while WG2 defined a standard architecture and related interfaces of reconfigurable MD. In this paper, we have presented systematic procedures of the reconfigurable MD of which the architecture is compliant with the ETSI standard for the realization of the LSA-based spectrum sharing. In the proposed procedures, we have specified what data transfers should occur in what order in the reconfigurable MD of ESI standard architecture. It has been shown in this paper that the reconfigurable MD with the standard architecture can provide the LSA-based spectrum sharing. Since the target MD is reconfigurable with the ETSI standard architecture, not only the frequency-related parameters such as operating frequency, TX bandwidth, TX power, and RX sensitivity, but also the modem-related parameters such as modulation scheme, precoding, etc can be adaptively optimized according to the communication environments of the new spectral band.

The future work will be focused on the implementation of the reconfigurable MD. This work can be used to compare the performance of reconfigurable MD with that of conventional non-reconfigurable MD.

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