A Radio-Resource Switching Scheme in Aggregated Radio Access Network

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***Abstract* – In an aggregated radio access network (A-RAN), wherein multiple radio access technologies (RAT) coexist, different radio resource utilization in each RAT may result in decreasing quality of service (QoS). In this paper, we propose a radio resource switching scheme in A-RAN coexist to provide multi-modal mobile users with the best service using a cloud base-station concept. The proposed scheme is manipulated to optimize radio utilization and QoS.**

Keywords: radio-resource; cloud; radio-access-network.

I. INTRODUCTION

The widespread and increasing use of smart-phones and broadband based services such as high-quality video and peer-to-peer services has caused the explosion of data traffic in mobile networks. To cope with this surge of data traffic, new technologies such as the WiMAX [1] and LTE [2] families have been implemented in a short period. Therefore, these newly deployed systems are likely to coexist with legacy systems, with each owning a separately their radio access network, resulting in high capital expenditure/operating expenditure (CAPEX/OPEX). Moreover, dynamic variations in traffic load may cause lower average utilization of a base station. To settle these challenges, a cloud-conceptual base station system has been introduced. Through virtualization using cloud technologies, any user equipment (UE) is able to access one of the common cell-sites, behind which multiple radio access technologies (RATs) are used to service a user-specific traffic in the best possible manner. We call such a network with multi-RATs, an aggregated radio access network (A-RAN). In A-RAN, it is also anticipated that software-defined radio equipment for signal processing of each radio access technology (RAT) provides the capability of sharing radio resources between different RATs to optimize frequency usage. In this paper, we propose a scheme to switch radio resources between the different radio access technologies used within an aggregated radio access network (A-RAN) to increase spectrum utilization.

The rest of this paper is organized as follows. The system to which our proposed scheme is applied is described in Section II. The proposed scheme to switch radio resources is described in Section III. The current simulation system, discussion, and further works to fulfill our study are presented in Section IV. Finally, Section V summarizes our conclusions.

II. SYSTEM MODEL

A. *Aggregated radio access network architecture.*

A-RAN has been developing to reduce network implementation and maintenance costs as well as to increase efficiency of hardware usage. Some A-RAN models have been introduced such as KT CCC (Cloud Communication Center) [3], Alcatel-Lucent lightRadio [4] or C-RAN of China Mobile Research Institute [5]. Fig. 1 shows the generalization of A-RAN architectures mentioned above. The A-RAN consists of Radio Units (RUs) and Digital Units (DUs), as shown in Fig. 1. A DU performs all of the functions performed by a traditional base station transceiver (BTS) and base station controller (BSC) in a legacy system, including baseband signal processing of user data, radio-resource allocation, and various control functions. On the other hand, an RU only has a physical radio interface comprising an antenna and power amplification. By centralized processing and control functions in DU, DU can be built on cloud computing environment to optimize hardware utilization as well as using software-defined radio equipments to have flexible capability of processing any baseband signals.

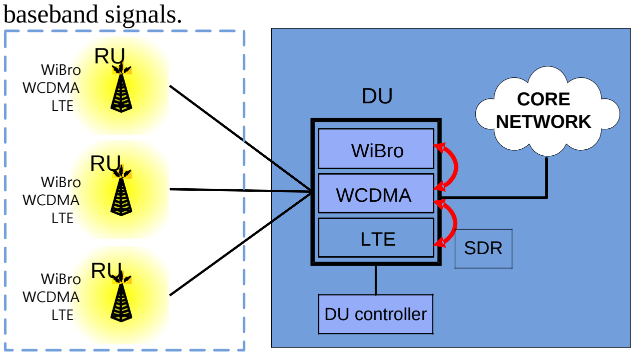

Figure 1. A-RAN architecture.

B. *System model*

In our study, we assume three different wireless access systems: A, B, and C. These systems are characterized by the carried traffic types such as packet or circuit-switched and the availability of carrier aggregation, a functionality introduced for broadband services in the LTE-Advance

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standard [6]. The descriptive parameters of the three above mentioned systems are summarized in Table 1.

TABLE I. SYSTEM PARAMETERS

Parameters	System A	System B	System C
System bandwidth (MHz)	40	40	20
Channelization (MHz)	20, 10, 5, 5	20, 10, 5, 5	5, 5, 5, 5
Carrier aggregation	Yes	No	No
Traffic type	Packet traffic	Packet traffic	Circuit traffic
Frame length (ms)	10	10	N/A

Systems A and B have LTE-like orthogonal frequency division multiple access (OFDMA) channel architectures [7], in which the time axis is divided into 10-ms frames that are further subdivided into ten 1-ms slots. In the frequency domain, the subcarrier spacing is 1 MHz. In the 2-dimensional channel domain, a resource-allocation unit called a resource block (RB) is defined as 1 ms × 1 MHz [time × frequency]. There are three UE types: mode-A-only, which is capable of only accessing system A; mode-B-only, which is for system B only; and multi-modal UE, which is capable of using both systems A and B. On the other hand, system C is accessible to all UE for circuit traffic. Moreover, in terms of the channel handling capability, the UE is categorized as having 5, 10, 20, and 40 MHz capability.

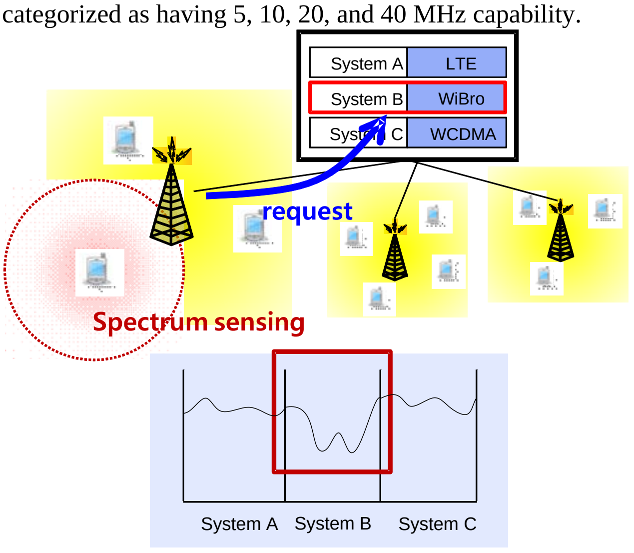

Figure 2. Spectrum map in UE

Before making a call request, a multi-modal UE performs a kind of preliminary preparation called early spectrum sensing (ESS). It measures the power levels over the entire frequency band of Systems A, B, and C and builds a spectrum map based on these measurements, as shown in Figure 2. Then, the UE tries to send a call request to the system that contains the lowest power level, which means that the frequency availability is the highest. When the target system receives UE request, if it has enough available resource and its average packet loss ratio over *N* frames is lower than packet loss threshold, it will admit the call. Otherwise, it consults DU controller about other available system. By checking remaining resource and packet loss ratio of other systems, DU controller informs target system of a new system that has enough free resource and average packet loss ratio over *N* frames is lower than packet loss threshold, and then target system signals to UE to send call request to the new one. If other systems also do not meet these two conditions, UE call request will be dropped, with real-time traffic, or put into buffer, with delay tolerance traffic.

III. PROPOSAL OF RADIO RESOURCE SWITCHING

DU is able to monitor the entire radio resource utilization for Systems A, B, and C, and control the amount of radio resources belonging to each system if needed. On that basis, we propose a scheme for switching radio resources between systems to ensure better system performance and higher resource utilization. The proposed scheme is illustrated using the flow chart shown in Figure 3.

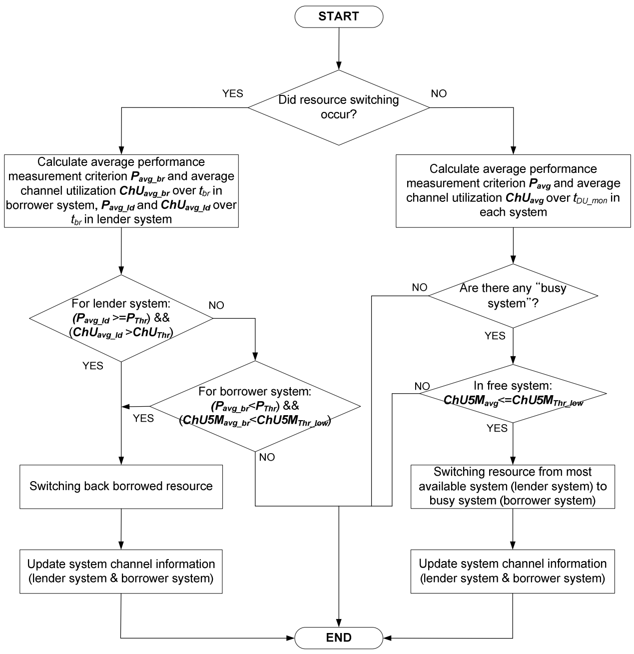

Figure 3. Proposed radio resource switching scheme

In our proposed scheme:

- If radio resource switching (RRS) has not yet occurred, DU calculates the performance measures for each period, t_{DU_mon}
- If RRS has occurred, DU calculates the performance measures for each period, t_{br}, in the borrower system to which the free radio resources are switched, and for each t_{ld} in the lender system from which free radio resources are switched.

We define a "busy system" as a system in which both the average packet loss rate over period t_{DU_mon}, P_{avg}, is higher than the packet loss threshold, P_{Thr}, and the average channel utilization over period t_{DU_mon}, ChU_{avg}, is higher than the channel utilization threshold ChU_{Thr}, which is 95 percentage capacity of all channels in system. If these two conditions do not occur simultaneously, we consider the system to be a "free system".

The operation of our scheme is described below. If radio resource switching has not yet occurred, the DU continuously monitors the average packet loss rate, P_{avg}, and average channel utilization, ChU_{avg}, in each system for each period, t_{DU_mon}. When it finds a busy system, it then checks the utilization of 5MHz channels ChU5M in the free systems: if it is lower than a threshold called $ChU5M_{Thr\_low}$:

$$ChU5M_{Thr\_low} = (num\_5M-1)/\ num\_5M \quad (1)$$

whereas num_5M is the number of 5MHz channels in free system, the DU will switch resources from the free system with the most available resources to the busy system. Then, each system will update its channelization information. If radio resource switching has already occurred, the DU calculates the average packet loss ratio, P_{avg_br}, and average channel utilization, ChU_{avg_br}, over t_{br} in the borrower system, along with the average packet loss ratio, P_{avg_ld}, and average channel utilization, ChU_{avg_ld}, over t_{ld} in the lender system. In the lender system, if both P_{avg_ld} and ChU_{avg_ld} are higher than thresholds P_{Thr} and ChU_{Thr}, respectively, the DU restores the lent resources to the system to which they belong. This means the lender system becomes busier and needs to recall its lent resources. In the case of the borrower system, if the following condition happens

$$P_{avg\_br}<P_{Thr}\ \&\ ChU5M_{avg\_br}<ChU5M_{Thr\_low} \quad (2)$$

the DU restores the lent resources to the original system. This indicates that the load on the borrower system is decreasing and it may no longer need the additional resources. When monitoring system C, packet lost ratio is replaced by call block probability.

In A-RAN, channel processing modules of system can be software-defined radio equipments. So it is able to switch radio channel from one system to other system by re-configure the software of channel processing module.

IV. ONGOING SIMULATION

A. *Simulation environment*

We start the computer simulation under a single-cell condition with a static UE number, but will eventually consider multi-cell environments and user mobility with handoffs between them. UEs are distributed uniformly in cell coverage. DU manages a finite-length buffer for each user in order to store data coming from the core network side. If the buffer overflows, the packets are lost. In this paper, the packets are categorized as real-time packet and delay-tolerant packet, with tolerances ranging from one to three frames. The traffic generation of user *n* is modeled as a Poisson arrival process with rate λ_n, $n \in \{1,2,\ldots N\}$. Then, the total arrival rate is

$$\lambda_{all} = \sum_{n=1}^{N} \lambda_n \quad (3)$$

The traffic volume is normalized by the number of RBs needed to carry it.

B. *Initial simulation result*

In this part, we will discuss our initial simulation result.

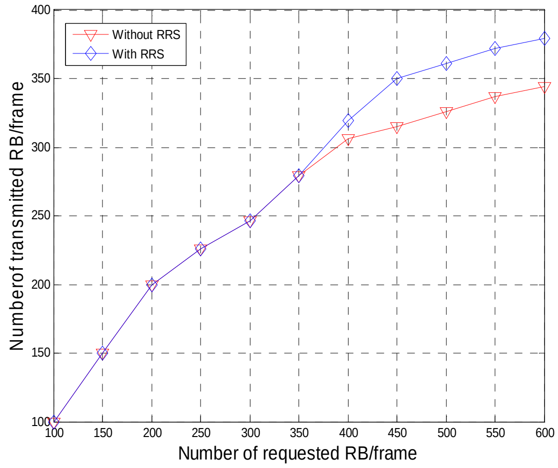

Figure 4. System performance

Fig. 4 compares the system throughput when radio resource switching is used and when it is not used. RRS helps to improve system throughput. Additional simulations will help us ensure that packet lost ratio with RRS is lower than without RRS.

V. CONCLUSION AND FUTURE WORKS

In this paper, a radio resource switching scheme was proposed for application to an A-RAN based on the deployment of a cloud base-station in order to improve frequency utilization, increase system throughput, and enhance the QoS. We expect that after the system simulations are completed, the simulation results will validate the performance enhancement of the proposed scheme. In the next step, we will consider this scheme in an environment closer to reality, i.e., system parameters are same as defined in standards.

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