A Bandwidth Adaptation Scheme for Cloud Radio Access Networks

Yuh-Shyan Chen, Fang-Yu Liao, and Yi-Kuang Kan(✉)

National Taipei University, Taipei, Taiwan, R.O.C.
yschen@mail.ntpu.edu.tw, fangyu1313@gmail.com, david3343559@gmail.com
http://www.csie.ntpu.edu.tw/~yschen/

Abstract. With the advent of Cloud Radio Access Networks (C-RAN) where base band units (BBU) have the ability to dynamically support the bandwidth allocation and centrally manage the bearers transmitted from the remote radio heads (RRH), bandwidth adaptation (BA) mechanism emerges as a promising solution to provide the required resources for C-RAN to provide resources to the bearers during congestion. Existing studies use BA mechanism on congestion management only for LTE system but rarely for C-RAN. To achieve this goal, this paper takes the advantage of dual connectivity with the ability of bearer split to cooperatively provide resources by the serving RRHs, at the same time the mobility robustness and the throughput performance can be improved. The main contribution of this work is to propose an improved BA mechanism for C-RAN with dual connectivity in a centralized concept. More specifically, this work designs a "downgrading index" includes two additional centralized contribution attribute to decide the proportional resource contribution of the bearers which are transmitted by the chosen RRHs and are grouped to assist the serving RRHs. Finally, simulation results illustrate the proposed BA mechanism for C-RAN with dual connectivity significantly reduces the probabilities of the handoff bearer dropping and the bearer blocking.

Keywords: C-RAN · Dual connectivity · Bandwidth adaptation · Call admission control · Handoff

1 Introduction

The fifth generation (5G) cellular wireless networks are expected to overcome the amount of data traffic which is being increasing dramatically in recent years [1]. As a consequence, the mobile operators need to spend more for building, operating and upgrading the traditional Decentralized Radio Access Networks (D-RAN) while the revenue does not balance with the cost. To find feasible solutions emerging in the future, China Mobile has been developing and deploying Cloud Radio Access Networks (C-RAN) which is believed to be an answer to the challenges [2]. Moreover, Mobile and wireless communications Enablers for

Y. Zhou and T. Kunz (Eds.): ADHOCNETS 2016, LNICST 184, pp. 234–245, 2017.
DOI: 10.1007/978-3-319-51204-4_19

Twenty-twenty (2020) Information Society (METIS) proposed that the 5G architecture trends to embrace C-RAN to have a scalable and centralized control [3]. With centralized processing of C-RAN by separating the base band units (BBU) and remote radio head (RRH), the architecture has the advantage of upgrading and expanding the network capacity. In this respect, operators can have a large saving in cost. However, the bearer would be blocked if there is no idle bandwidth to be allocated by the BBU in C-RAN. To overcome the problems mentioned above, this work proposes an improved BA mechanism with centralized concept in C-RAN. The improvement downgrades resources not only from the requested RRH but from the managed RRHs. To find suitable RRHs to assist the requested RRHs, the BBU discovers the candidate group, G_c and the assistance group, G_a. The detailed definition of G_c and G_a is described in Sect. 3. Moreover, to decide how much resources each bearer from G_a shall release, according to the proportional resource contribution of downgrading index which includes four contribution attributes. This paper designs two contribution attributes in a centralized concept. Therefore, each bearer from G_a only needs to partially release resources to provide enough resources and the resources from the serving RRHs can be decreased.

A GBR bearer is associated with a bearer priority, denoted as i, and a GBR parameter denoted as R_{gi} and a Maximum Bit Rate (MBR) parameter denoted as R_{mi}. To propose an improved BA mechanism includes the above-mention two main QoS parameters, R_{gi} and R_{mi}, this paper also takes dual connectivity which is in 3GPP LTE release 12 [4], is considered in the future of 5G architecture, into account. A term "dual connectivity" refers to the operation with the ability of bearer split where a given UE consumes radio resources provided by one master eNB (MeNB) and one secondary eNB (SeNB). Adopt dual connectivity to C-RAN architecture, the serving RRH with larger transmission coverage can substitute for the role of MeNB, where RRH_m is denoted as the master RRH. Similarly, the other serving RRH with smaller transmission coverage can substitute for the role of SeNB, where RRH_s is denoted as the secondary RRH. Hence, the mobility robustness and the per-user throughput can be improved in C-RAN. Furthermore, a UE consumes radio resources provided by RRH_m and RRH_s causes RRH_m and RRH_s can cooperatively provide resources to the UE. In sum, the objective of this paper is not only proposing an improved BA mechanism that is suitable in C-RAN but taking the advantage of dual connectivity to deal with the resource management in congestion.

The remainder of this paper is organized as follows. In Sect. 2, related work and motivation are described. Section 3 describes the system model, problem formulation and basic idea of the proposed scheme. Section 4 describes the proposed improved BA mechanism for C-RAN with dual connectivity. Simulation results are presented Sect. 5. Section 6 concludes this paper.

2 Related Works

Regarding other existing BA mechanisms by taking the advanced QoS requirements into account, some results are discussed. Khabazian *et al.* [5] proposed a fairness-based preemption algorithm which takes into consideration the bearer priority as well as the amount of the QoS over-provisioning of the bearers. According to the two matrix to have the downgrading index, the contribution of each bearer is computed to release resources in a fairness way. Moreover, the downgrading index can be fine-tuned to have a optimize performance gain by the operator. More recently, Khabazian *et al.* [6] proposed a multi-objective and distributed BA mechanism which takes three bearer attributes into account namely bearer priority, bearer QoS over-provisioning and bearer communication channel quality. With fine-tuning exponents, the performance measurement can be reached a tradeoff. All the related works are proposed the designed BA mechanisms focus on D-RAN architecture, which are not designed for C-RAN.

3 Preliminaries

Considered the downlink C-RAN architecture of handover scenario, the system model is illustrated as shown in Fig. 1(a), where all the RRHs and the BBUs are separated from the BSs and then the RRHs are connected to the BBUs in centralized BBU pool through the fronthaul. In the proposed protocol, only the resource management of resource blocks usage in bandwidth is considered. Moreover, the bandwidth can be dynamically allocated by the BBUs according to the load of controlled RRHs. Therefore, the traffic congestion in some RRHs can be avoided due to the RRHs contribute the idle PRB resources to the busiest RRHs by the centralized BBUs during congestion.

On the other hand, due to the fact that dual connectivity is considered in C-RAN, the UE can consume radio resources provided by RRH_m and RRH_s. In the proposed protocol, RRH_m is managed by BBU_m, while $RRH^{k,r}$ that transmits the radio resources to the UE is also presented as RRH_s, where $RRH^{k,r}$ is the r^{th} RRH managed by BBU_k. In Fig. 1(a), when the UE is moving to the transmission range of $RRH^{1,1}$, where RRH_m transmit resources to the UE plays the role of master RRH, and $RRH^{1,1}$ plays the role of secondary RRH is also presented as RRH_s. Both the RRH_m and RRH_s transmit radio resources to the UE.

To avoid experiencing strong interference from the macro and small RRHs when they are operated on the same frequency in the C-RAN architecture with dual connectivity [4], the bandwidth of channel is divided into two different parts. As shown in Fig. 1(b), the RRH_m with larger transmission range operates the lower frequency bands, *i.e.*, a GHz. Meanwhile, the other RRHs with smaller transmission range operate the higher frequency bands, *i.e.*, b GHz. Note that if the RRHs have transmission range overlap, then the bandeidth can be reassigned. Besides, Fig. 1(b) illustrates the downlink resource block. In 3GPP LTE release 12 [7], a physical resource block is defined as N_{sy} consecutive OFDM symbols in one downlink slot, T_s, and N_{sc} consecutive subcarriers in the frequency domain. Therefore, a PRB in the downlink consists of $N_{sy} \times N_{sc}$ resource elements during two downlink slot T_s.

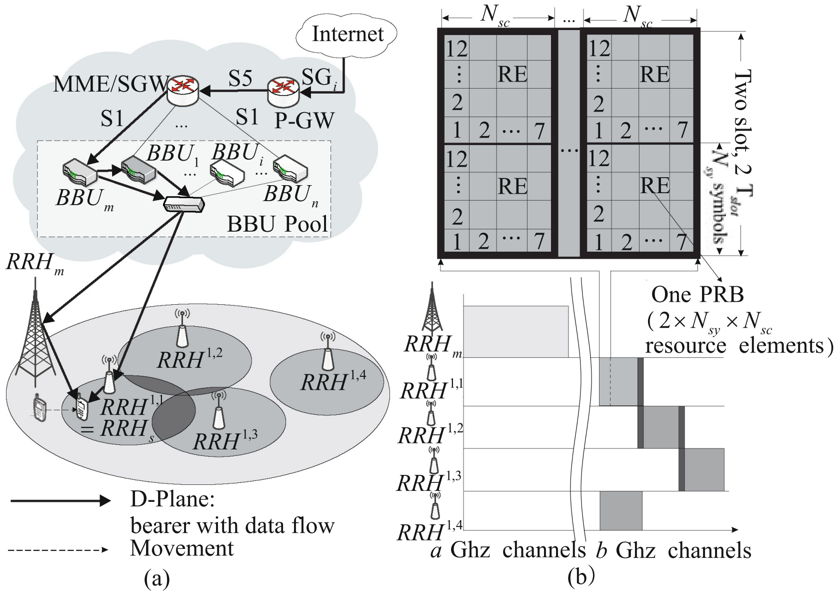


Fig. 1. System model of C-RAN with dual connectivity and channel operation.

3.1 Basic Idea

The basic idea of this work is by taking the advantage of C-RAN with dual connectivity to discover more resources from the chosen RRHs as assistants to assist RRH_m and RRH_s for establishing a new bearer. Moreover, this work designs a downgrading index that is suitable in the architecture in concept of centralized characteristic. When performing the centralized CAC scheme, the RRHs in G_c assist RRH_m and RRH_s to contribute more idle PRB resources. When performing the centralized BA algorithm to release enough resources, the RRHs in G_a assist to release more PRB resources for establishing new bearer. Based on this concept, the probability of a bearer request blocking and handoff bearer dropping can be significantly reduced by the assistance of the RRHs in G_c and G_a as well as the designed downgrading index to decide the proportional released resources of the active bearers.

4 A Bandwidth Adaptation Mechanism for Cloud Radio Access Networks

This section presents the improved BA mechanism for C-RAN with dual connectivity, three phases are described in the following.

4.1 Group Discovery Phase

The group discovery phase aims to find G_c and G_a first. If the resources are not enough when performing the centralized CAC phase, the RRHs in G_c can assist to release idle PRB resources. If the idle resources are not enough, the RRHs is G_a can release resources when performing the centralized BA phase. The procedure is given as follows.

S1. To discover G_c, the BBU which controls RRH_s selects the transmission range of the RRHs which are overlapped with RRH_s or the RRHs in G_c to form G_c.

S2. After discovering G_c, the BBU simply sorts the RRHs according to the QoS over-provisioning ratio $u^{k,r}$ of the RRHs in decreasing order. Let $u^{k,r}$ denote the QoS over-provisioning ratio of $RRH^{k,r}$, then $u^{k,r}$ can be expressed as follows.

$$\begin{aligned} u^{k,r} &= \frac{\sum_{i,j} \gamma_{i,j}^{k,r}}{\sum_{k,r,i,j} \overline{b_{i,j}^{k,r}}}, \\ \text{where} \quad \gamma_{i,j}^{k,r} &= \overline{b_{i,j}^{k,r}} - b_{i,j}^{k,r}(R_{gi}), \\ RRH^{k,r} &\in G_c \end{aligned} \tag{1}$$

where $\overline{b_{i,j}^{k,r}}$ denoted as the load contribution measured by the technology, $b_{i,j}^{k,r}(R_{gi})$ denoted as the resources the bearer $b_{i,j}^{k,r}$ requests to meet the guarantee bit rate R_{gi} with priority i. Therefore, the QoS over-provisioning resources of $b_{i,j}^{k,r}$ denoted as $\gamma_{i,j}^{k,r}$, where $\gamma_{i,j}^{k,r}$ is the resources $b_{i,j}^{k,r}(R_{gi})$ deducted from the allocated resource $\overline{b_{i,j}^{k,r}}$. The larger $u^{k,r}$ means the more bearers $b_{i,j}^{k,r}$ in $RRH^{k,r}$ take more resources that exceed their R_{gi}.

S3. After obtaining the QoS over-provisioning ratio order of each RRH, then G_a can be found. Select the $RRH^{k,r}$ in G_c with $u^{k,r}$ that higher than the threshold θ to form G_a. Note that the lower θ is, the more RRHs can be selected to form G_a, and the more bandwidth usage of RRHs are influenced to release resources. On the other hand, the higher θ is, the less RRHs are selected to form G_a, thus the more difficult to release enough resources.

An example of the group discovery phase is given in Fig. 2. The serving RRHs are RRH_m and $RRH^{1,1}$, where $RRH^{1,1}$ also represents RRH_s. To discover G_c, the transmission range of $RRH^{1,2}$ and $RRH^{1,3}$ are found overlapped with RRH_s. Therefore, $RRH^{1,2}$ and $RRH^{1,3}$ are added to G_c. Moreover, the transmission range of $RRH^{1,4}$ and $RRH^{1,5}$ are overlapped with that of the RRHs in G_c. Therefore, $RRH^{1,4}$ and $RRH^{1,5}$ are added to G_c. To discover G_a, according to the Eq. (1), the BBU sorts $u^{k,r}$ of $RRH^{k,r}$ in G_c and selects the $RRH^{k,r}$ with $u^{k,r}$ that higher than θ to form G_a. Assumes the order of QoS over-provisioning ratio is $u^{1,3} > u^{1,5} > u^{1,1} > u^{1,2} > u^{1,4}$, where $u^{1,3}$ and $u^{1,5}$ are higher than θ, which means $u^{1,3}$ and $u^{1,5}$ have more QoS over-provisioning resources than other RRHs to provide. Therefore, includes RRH_m and RRH_s ($RRH^{1,1}$), G_a is formed by $\{RRH_m, RRH^{1,1}, RRH^{1,3}, RRH^{1,5}\}$.

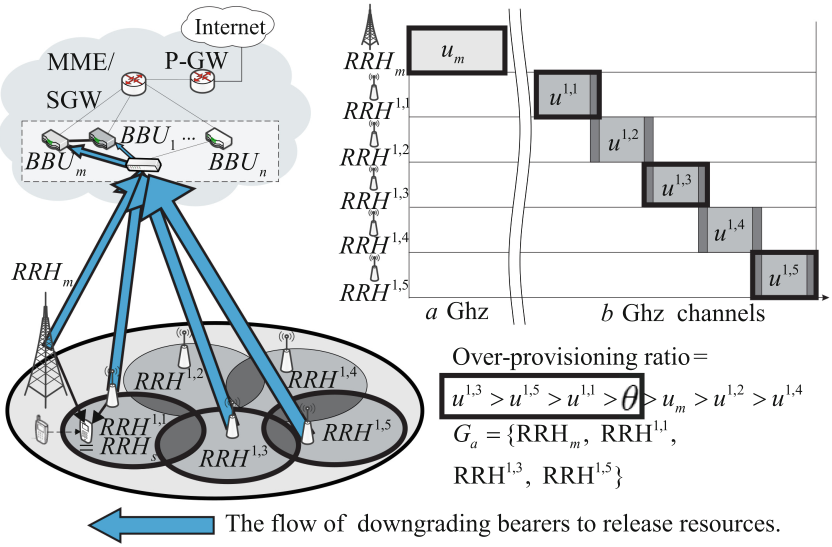


Fig. 2. Example of discovering the G_c and G_a.

4.2 Centralized CAC Phase

When an UE requests resources to establish a new bearer or maintain the rate of a handoff bearer, the CAC policy is performed to decide whether there are enough resources for the bearer admitting to establish. Here the centralized CAC phase aims to enhance the exiting CAC scheme [6] and propose a centralized CAC policy that is considered the centralized characteristic of C-RAN with dual connectivity. Let $n_i^{k,r}$ denote the amount of bearers with priority i that transmitted by $RRH^{k,r}$ and managed by BBU_k. A new bearer or a handoff bearer is the $(n_i^{k,r}+1)$-th. Let $b^{k,r}_{i,n_i^{k,r}+1}(R)$ denote a new bearer $(n_i^{k,r}+1)$-th requests resources to meet bit rate R and let $CQI^{k,r}$ denote the reported CQI value from the UE to $RRH^{k,r}$. Let $C^{k,r}$ denote the total capacity of $RRH^{k,r}$ in OFDM PRB. The procedure is given as follows.

S1. When a new bearer or a handoff bearer $b^{k,r}_{i,n_i^{k,r}+1}$ requests PRB resources $b^{k,r}_{i,n_i^{k,r}+1}(R)$ to meet bit rate R, RRH_m and RRH_s provide resources in a proportional way. The original request resources $b^{k,r}_{i,n_i^{k,r}+1}(R)$ divided to $b^{k,r}_{i,n_i^{k,r}+1}(R^{k,r})$ to request from the serving $RRH^{k,r}$ according to their $CQI^{k,r}$. To express the proportional resources each serving $RRH^{k,r}$ needs to provide, $b^{k,r}_{i,n_i^{k,r}+1}(R^{k,r})$ can be expressed as follows:

$$b^{k,r}_{i,j}(R^{k,r}) = b^{k,r}_{i,j}(R) \times \frac{CQI^{k,r}}{\sum\limits_{k,r,i,j} CQI^{k,r}}, \quad \text{where} \quad RRH^{k,r} \in RRH_m \cup RRH_s, \tag{2}$$

the serving $RRH^{k,r}$ only need to provide the proportional contribution of $b_{i,j}^{k,r}(R^{k,r})$.

S2. To ensure that the total idle PRB resources in the serving $RRH^{k,r}$ is enough to provide their $b_{i,j}^{k,r}(R^{k,r})$, $Cp^{k,r}$ is denoted as the prediction remaining resources of $RRH^{k,r}$.

$$Cp^{k,r} = (C^{k,r} - \sum_{m=1}^{9}\sum_{n=1}^{n_i^{k,r}} \overline{b_{m,n}^{k,r}}) - b_{i,j}^{k,r}(R^{k,r}) \tag{3}$$

to obtain $Cp^{k,r}$, all the allocated resources to the bearers in $RRH^{k,r}$ need to be deducted from $C^{k,r}$, *i.e.*, $(C^{k,r} - \sum_{m=1}^{9}\sum_{n=1}^{n_i^{k,r}} \overline{b_{m,n}^{k,r}})$, and then deduct the requested proportional resources $b_{i,j}^{k,r}(R^{k,r})$. Where the bearer priority is from 1 to 9. If one of the $Cp^{k,r}$ from the serving $RRH^{k,r}$ is negative, which means the idle PRB resources of $RRH^{k,r}$ is not enough to provide the proportional resource $b_{i,j}^{k,r}(R^{k,r})$, then the BBU checks the requested bit rate. If the requested bit rate $b_{i,j}^{k,r}(R)$ is larger than $b_{i,j}^{k,r}(R_{gi})$, which means the request bit rate is larger than the guarantee bit rate, then sets $b_{i,j}^{k,r}(R)$ to $b_{i,j}^{k,r}(R_{gi})$. Therefore, the procedure is back to S1 to compute $b_{i,j}^{k,r}(R^{k,r})$ again to obtain the new $b_{i,n_i^{k,r}+1}^{k,r}(R^{k,r})$ of serving $RRH^{k,r}$.

S3. If the requested bit rate is $b_{i,j}^{k,r}(R_{gi})$ and one of $Cp^{k,r}$ is still negative, then RRH_m and RRH_s need to assist each other. By summarizing all $Cp^{k,r}$, if the value of $\sum_{k,r} Cp^{k,r}$ larger or equal to zero which means one serving RRH whose $Cp^{k,r}$ is positive and can contribute the remaining resources to the other RRH whose $Cp^{k,r}$ is negative. Otherwise, the RRHs in G_c need to provide idle PRB resources to assist RRH_m and RRH_s. To obtain new request resources $b_{i,j}^{k,r}(R^{k,r})$ from each serving $RRH^{k,r}$, let $Cr^{k,r}$ denote the actual remaining resources, where $Cr^{k,r} = C^{k,r} - \sum_{m=1}^{9}\sum_{n=1}^{n_i^{k,r}} \overline{b_{m,n}^{k,r}}$, then Eq. (4) can re-assign the request resources in an assistance way.

$$b_{i,j}^{k,r}(R^{k,r}) = \begin{cases} b_{i,j}^{k,r}(R^{k,r}) + (Cp^{k,r} - \sum_{k,r} Cp^{k,r}), \\ \text{if } Cp^{k,r} > 0 \\ Cr^{k,r}, \text{if } Cp^{k,r} \leq 0 \quad \text{or} \quad \sum_{k,r} Cp^{k,r} \leq 0 \end{cases} \tag{4}$$

therefore, the RRH whose $Cp^{k,r}$ is negative only need to provide the remaining resources $Cr^{k,r}$.

S4. If the steps from S1 to S3 cannot release enough resources by the RRHs in G_c and RRH_m with RRH_s, which can be expressed as follow.

$$S_{PRB}^{idle}(G_c) + \sum_{k,r} Cp^{k,r} < 0, \text{where } S_{PRB}^{idle} \in G_c \tag{5}$$

where S_{PRB}^{idle} denoted as the idle PRB resources, and $S_{PRB}^{idle}(G_c)$ denoted as the idle PRB resources from the RRHs in G_c. If $S_{PRB}^{idle}(G_c)$ cannot fill the insufficient resources of RRH_m and RRH_s, which means $S_{PRB}^{idle}(G_c)$ adds $\sum_{k,r} Cp^{k,r}$ still negative, then the proposed BA algorithm is performed to downgrade bearers to release request resources $b_{i,j}^{k,r}(R)$. Otherwise, the admission is failed then the bearer would be dropped.

4.3 Centralized BA Phase

The centralized BA phase aims to downgrade bearers from the RRHs in G_a to release enough resources. Before downgrading the bearers, the downgrading index is calculated to decide the proportional release resources. The downgrading index includes four attributes in this paper. In addition to take the two bearer attribute. After obtaining the value of downgrading index of the bearers, the centralized BA algorithm is performed to release resources in a fair way.

S1. To compute the needed resources of each bearers from RRHs in G_a to be released, the downgrading index $d_{i,j}^{k,r}$ need to be obtained, which includes four attributes. The first attribute is the bearer priority, which is denoted as i. The higher the bearer priority is, the lower the number is, and the less resources need to be released. The second attribute is the QoS over-provisioning resources, which is denoted as $\gamma_{i,j}^{k,r}$ in Eq. (1). At most the resources $\overline{b_{i,j}^{k,r}}$ can downgrade $\gamma_{i,j}^{k,r}$ to $b_{i,j}^{k,r}(R_{gi})$ in order to ensure each bearer can still meet its R_{gi}. The first two attributes are regarding the bearer itself, and the last two attributes are regarding the C-RAN architecture. Thus the attributes are in a hierarchical structure to decide the downgrading index.

S2. The last two attributes are in relation to RRH channel quality and BBU period popularity. The third attribute is the RRH channel quality. This paper takes the CQI as the channel quality from UE to the RRHs in G_a. The larger the CQI, the more resources the RRH needs to be released. It is because that with higher CQI, the RRH can provide less resource to meet the same bit rate compared to the RRH with lower CQI. Moreover, the attribute can have RRH_m and RRH_s provide more proportional of contribution. To denote $\text{CQI}^{k,r}$ of $RRH^{k,r}$ in G_a, the RRH channel quality $q_{k,r}$ can be written as follows.

$$q_{k,r} = \begin{cases} \text{CQI}^{k,r}, & \text{if } \text{CQI}^{k,r} > 1 \\ 1, & \text{otherwise.} \end{cases} \tag{6}$$

the UE may out of range from the RRHs in G_a, in order to avoid having the value of q_r be 0, the minimum value of q_r is set to 1. Finally, the fourth attribute is the period popularity of BBU which manages the RRHs in G_a. This paper takes the resource utilization to measure the popularity of a BBU in a period. If a BBU has larger period popularity, which predicts the next period the BBU may need to provide more resources to the coming bearers.

Let ξ_k denote the period popularity of BBU_k, then ξ_k can be written as follows.

$$\xi_k = \frac{\sum_{i,j,r} \sum_{t=T_s}^{T_e} \overline{b_{i,j}^{k,r}(t)}}{C(T_s - T_e)} \tag{7}$$

ξ_k is obtained from estimating the fraction of the total bandwidth capacity, which denoted as C, and the total resources allocated to the bearers which are established from BBU_k over an observation time period from T_s to T_e sub-frames. From the view of the prediction of the popularity, if BBU_k has higher ξ_k, then the bearers in BBU_k better not release more resources in order to save the resources to serve the future needed bearers. For the ease of the comparison of the resource utilization, ξ_k need to be normalized as follows.

$$\xi_{nor,k} = (1 - \frac{\xi_k}{\sum_{k \in \mathrm{RRH}^{k,r}} \xi_k}) \cdot \sum_{k \in \mathrm{RRH}^{k,r}} \xi_k \tag{8}$$

S3. After obtaining the four attributes to obtain the value of downgrading index for downgrading each bearers from G_a, the downgrading index is denoted as follows.

$$d_{i,j}^{k,r} = i^{\alpha}(\gamma_{i,j}^{k,r})^{\beta} q_{k,r}^{\omega} \xi_{nor,k}^{\delta}, \text{ where } \quad \alpha + \beta + \omega + \delta = 1 \tag{9}$$

the purpose of adding the four exponents including α, β, ω, and δ is that the downgrading index results in a different effect. With larger δ, the larger the BBU utilization need not to release more resources. Note that the sum of the four exponents is 1. To obtain the fraction of the resources each bearer need to be released from the RRHs in G_a, $d_{i,j}^{k,r}$ need to be normalized. The normalized downgrading index $\overline{d_{i,j}^{k,r}}$ can be expressed as follows.

$$\overline{d_{i,j}^{k,r}} = \frac{d_{i,j}^{k,r}}{\sum_{k,r,i,j} d_{i,j}^{k,r}} \tag{10}$$

after obtaining the normalized downgrading index $\overline{d_{i,j}^{k,r}}$ of $b_{i,j}^{k,r}$ in G_a, the centralized BA algorithm is performed to release resources.

S4. With the obtained value of $\overline{d_{i,j}^{k,r}}$ of $b_{i,j}^{k,r}$, a centralized BA algorithm is presented to calculate the resources each bearer need to be released. This operation re-allocates the resources to all the bearers from G_a according to the fraction of $\overline{d_{i,j}^{k,r}}$ of $b_{i,j}^{k,r}$. After the operation, the CAC scheme can decide to admit the new bearer or not. In the centralized BA algorithm, this paper includes a centralized approach and applies the idea of the BA algorithm proposed by [6] because which can release resources in a proportional and fair way.

5 Simulation Results

This paper presents an improved BA mechanism for C-RAN with dual connectivity in centralized concept. To evaluate the improved BA mechanism (denoted as proposed scheme), the proposed scheme is simulated compared to the BA mechanism that proposed by Khabazian *et al.* [6] (denoted as distributed Khabazian scheme). However, the distributed Khabazian scheme is designed for D-RAN and is not under the assist of dual connectivity. In order to compare the two scheme in a fair way, this paper also compared the distributed Khabazian scheme with dual connectivity (denoted as distributed Khabazian scheme with DC) under D-RAN. These three protocols are simulated using the Network Simulator-2 (NS2) and the models and assumptions are based on 3GPP assumptions [4]. The main parameters and the classes of the bearers with their GBR and MBR are shown in Table 1. To ensure that the total value of $\alpha + \beta + \omega + \delta$ are equal to 1, the simulation aims to focus on the effect of the main exponents which are set to the same value (0.91) in the two protocol. To discuss the effect of the bearer request arrival rate and the number of RRHs of D-RAN and C-RAN, the performance metrics to be observed are:

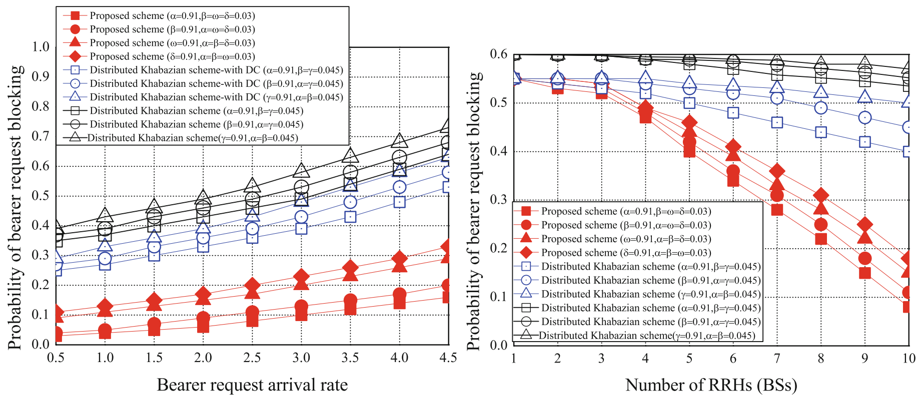
- *Probability of bearer request blocking* (PBRB): The failure probability of establishing a bearer. If a bearer requests resources for establishing but there are not remaining resources for the bearer, then the bearer is not admitted by the CAC scheme.
- *Probability of handoff bearer dropping* (PHBD): The failure probability of maintaining a handoff bearer. If a handoff bearer requests resources from the target eNB or RRH but there are not remaining resources for the handoff bearer, then the bearer is not admitted by the CAC scheme.

5.1 Probability of Bearer Request Blocking (PBRB)

Figure 3(a) shows as the bearer request arrival rate increases, the PBRB increases because the more requests arrive causes congestion occurs and thus increases the PBRB. Observe that the PBRB of the proposed scheme is lower than the distributed Khabazian schem in each parameter of the exponential tune value, as shown in Fig. 3(a). Due to there are more resources can be discovered by the centralized characteristic and the assistance of the RRHs in G_a and the RRHs in G_c, therefore, the more bearers are not be dropped. Figure 3(b) shows the PBRB observed by tuning the umber of RRHs. The higher the number of RRHs is, the higher the PBRB will be. As the number of RRHs increases, the more idle PRB resources can be discovered and because the BBU finds other unused bandwidth to assist to establish the new bearer. The proposed scheme is better than the distributed Khabazian scheme because the distributed Khabazian scheme cannot find other RRHs to contribute their resources. On the other hand, the proposed protocol discovers more resources thus the PBRB reduces when the bearer request arrival rate and the number of RRHs is increased. Moreover,

Table 1. Simulation parameters.

Parameter	Value
Simulation time	1000 s
System bandwidth	Macro cell:10 MHz, Small cell:10 MHz
Carrier frequency	Macro cell:2.0 GHz, Small cell:5.0 GHz UE:2.0/5.0 GHz
Moving speed	3 km/h
Inter-site distance	500 m
Number of small cells	7 in macro cell sector
Number of UEs	Uniform distribution with max = 60
Bearer classes	GBR-bearer with priority 1 GBR = 32 kb/s, MBR = 64 kb/s GBR-bearer with priority 2 GBR = 128 kb/s, MBR = 256 kb/s GBR bearer with priority 3 GBR = 10 kb/s, MBR = 64 kb/s



(a) (b)

Fig. 3. (a) Probability of handoff bearer dropping vs. bearer request arrival rate. (b) Probability of handoff bearer dropping vs. number of RRHs (BSs).

the distributed Khabazian scheme with DC has higher performance than distributed Khabazian scheme for the reason that with DC, the UE can have more bandwidth to use.

6 Conclusions

An improved BA mechanism that is suitable in C-RAN with dual connectivity is proposed. The proposed improved BA mechanism takes C-RAN with dual connectivity architecture and designs G_a from G_c to assist to release resources. Moreover, the designed downgrading index adds two additional contribution attributes in a centralized concept. Finally, simulation results illustrate the proposed BA mechanism for C-RAN with dual connectivity significantly reduces the probabilities of handoff bearer dropping and bearer blocking.

Acknowledgement. This research was supported by the Ministry of Science and Technology of the ROC under Grants MOST-103-2221-E-305-005-MY3.

References

1. Demestichas, P., Georgakopoulos, A., Karvounas, D., Tsagkaris, K., Stavroulaki, V., Lu, J., Xiong, C., Yao, J.: 5G on the horizon: key challenges for the radio-access network. IEEE Veh. Technol. Mag. **8**(3), 47–53 (2013)
2. White Paper Version 2.5: C-RAN The Road Towards Green RAN. China Mobile Research Institute, June 2014
3. The METIS 2020 Project-Laying the foundation of 5G. https://www.metis2020.com/
4. 3GPP TR 36.842 V1.0.0, Evolved Universal Terrestrial Radio Access (E-UTRA); Study on Small Cell Enhancements for E-UTRA and E-UTRAN Higher Layer Aspects (Release 12). 3rd Generation Partnership Project (3GPP), November 2013
5. Khabazian, M., Kubbar, O., Hassanein, H.: A fairness-based preemption algorithm for LTE-Advanced. In: Proceedings of IEEE Global Telecommunications Conference (GLOBECOM 2012), Anaheim, America, pp. 5320–5325, December 2012
6. Khabazian, M., Kubbar, O., Hassanein, H.: An advanced bandwidth adaptation mechanism for LTE Systems. In: Proceedings of IEEE International Conference on Communications (ICC 2013), Budapest, Hungary, pp. 6189–6193, June 2013
7. 3GPP TS-36.211 v12.1.0, Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation. 3rd Generation Partnership Project (3GPP), March 2014