Pervasive and Mobile Computing ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Contents lists available at ScienceDirect

Pervasive and Mobile Computing

journal homepage: www.elsevier.com/locate/pmc

A bandwidth adaptation mechanism for Cloud Radio Access Networks

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ARTICLE INFO

Article history:
Available online xxxx

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

ABSTRACT

The Cloud Radio Access Network (C-RAN) is regarded as the possible implementation approach of the next-generation mobile networks. C-RAN splits a traditional base station into remote radio heads (RRHs) and the base band unit (BBU). Many BBUs are co-located into a centralized BBU pool. This enables the baseband resources to be managed in a centralized BBU pool and thus improves the efficiency. In this paper, a new bandwidth adaptation (BA) mechanism is designed for the C-RAN with the dual connectivity capability. The dual connectivity allows the bearer to be split so as to access more resources from RRHs simultaneously. The new BA mechanism is developed so as to dynamically allocate the resources to establish a new or a handoff bearer. The new BA mechanism is designed with a new downgrading index, which aims to fairly release the proportional resource from more RRHs and then aggregates the released resource to a new or a handoff bearer. Simulation and analysis results illustrate that the proposed BA mechanism reduces both the handoff bearer dropping and the bearer blocking probabilities.

1. Introduction

The mobile data volume has dramatically increased and hence the energy efficient, low-cost, and very-low latency transmission is required for the expanded traffic demands. Existing cellular networks cannot meet the requirements and hence the next-generation network, 5G, is expected to overcome the challenges [1,2]. The mobile operators spend high capital expenditure (CAPEX) and operating expense (OPEX) for building, operating, and upgrading the traditional Decentralized Radio Access Networks (D-RAN). To explore a new solution, a Cloud Radio Access Networks (C-RAN) is developed in to achieve the BS virtualization for the mobile 5G networks [3]. The main idea of C-RAN is to pool the Baseband Units (BBUs) from multiple base stations into centralized BBU Pool for statistical multiplexing gain [4]. The CAPEX/OPEX costs of the C-RAN architecture are low. Hence, C-RAN is adopted by the Mobile and wireless communications Enablers for Twenty-twenty (2020) Information Society (METIS) [5] as a 5G architecture.

A C-RAN can address the non-uniformly distributed traffic in cellular systems due to the load-balancing capability in the aggregated baseband unit (BBU) pool [6]. Based on the information of traffic data and bandwidth usage, the BBU pool can dynamically allocate the idle bandwidth among RRHs so as to increase the infrastructure utilization efficiency [7].

If RRHs cannot allocate physical resource blocks (PRB) for establishing a new bearer in the serving RRH, the bearer blocking occurs; if the existing bearer switches to a new RRH, but the new RRH cannot allocate physical resource blocks (PRB) for the handoff bearer, the handoff bearer dropping occurs. To overcome the bearer blocking and the handoff bearer dropping

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http://dx.doi.org/10.1016/j.pmcj.2017.06.023
1574-1192/

problems, a bandwidth adaptation (BA) mechanism is designed to reduce the probabilities of the bearer blocking and the handoff bearer dropping.

The BA mechanism reallocates the bandwidths of all active bearers to maximize the utility of a base station (BS) during the congestion periods. Before performing a BA mechanism, a call admission control (CAC) policy checks whether the remaining PRB resources are sufficient to establish a new bearer or maintain the same data rate of a handoff bearer. If there is not enough PRB resources in the requested BS to fulfill the requested resources, then the BA mechanism is performed. Compared C-RAN with D-RAN, once the remaining PRB resources are not enough to admit a new bearer in the requested RRH in C-RAN, a BBU can fully control the bandwidth of all the managed RRHs, and thus the BBU can allocate the idle bandwidth from other managed RRHs to the busiest RRH. If the managed RRHs of the BBU has no idle bandwidth, more resources needs to be released by the BA mechanism . The active bearers must be downgraded by releasing PRB resources so as to fairly contribute the needed PRB resources.

A Bearer is classified into two categories: Guaranteed Bit Rate (GBR) bearers and non-GBR bearers [8]. A GBR bearer is used for the VoIP application. A GBR bearer is associated with a bearer priority, denoted as i, and has two associated parameters which are GBR parameter, denoted as R_{gi}, and Maximum Bit Rate (MBR) parameter, denoted as R_{mi}. A GBR bearer is allowed to request bit rates that is higher than R_{gi} if there are available resources. These two important QoS parameters are used to guide the BA mechanism to release resources. A non-GBR parameter is used for web browsing or FTP transfer applications, which does not guarantee any bit rate transmission. The parameters of R_{gi} and R_{mi} of a non-GBR bearer is set based on the Allocation and Retention Priority (ARP) technique [9].

This paper proposes a BA mechanism for C-RAN with the dual connectivity capability, which is defined in 3GPP LTE release 12 [10]. The term "dual connectivity" refers to the operation with the ability of bearer split where a given UE consumes radio resources provided by a master eNB (called as MeNB) and one or more secondary eNBs (called as SeNBs) simultaneously. From the point of view of *mobility robustness* [11], the split configuration of C-plane bearer in MeNB and U-plane bearer in SeNB can be used to reduce the mobility signaling load. From the point of view of *per-user throughput* improvement [12], an ability called bearer split is used to split an U-plane bearer over multiple eNB. Thus, an UE can receive radio resources from more than one eNB to improve the throughput. Adopting the dual connectivity into C-RAN architecture, the serving RRH with larger transmission coverage can substitute the role of MeNB, where RRH_m is denoted as the master RRH. Similarly, the other serving RRH with smaller transmission coverage can substitute the role of SeNB, where RRH_s is denoted as the secondary RRH.

The objective of this paper is not only to propose a new BA mechanism in C-RAN but also to take the advantage of dual connectivity to effectively deal with the resource management. To the best of our knowledge, the BA mechanism for C-RAN with dual connectivity has not yet been studied before.

The main contributions of this paper is summarized as follows.

- The proposed BA mechanism is developed for C-RAN with the dual connectivity capability so as to improve the mobility robustness and the per-user throughput.
- The proposed BA mechanism centrally chooses the assisted RRHs to release resources, such that more resources from assisted RRHs can be contributed for establishing a new bearer or a handoff bearer.
- The proposed BA mechanism takes four bearers attributes, the bearer priority, the bearer QoS over-provisioning, RRH channel quality, and BBU period popularity, in the downgrading index. The downgrading index is used to fairly release resources when congestion condition occurred. Simulation results show that the probabilities of bearer blocking and handoff bearer dropping is reduced.

The remainder of this paper is organized as follows. In Section 2, related work and motivation are described. Section 3 describes the system model and basic idea of the proposed scheme. Section 4 describes the proposed improved BA mechanism for C-RAN with dual connectivity. Performance analysis is shown in Section 5. Simulation results are presented Section 6. Section 7 concludes this paper.

2. Related works

This section firstly describes related results in Section 2.1, then discusses centralized or distributed EPC in Section 2.2, and finally presents the motivation in Section 2.3.

2.1. Related results

Many existing works are developed to solve problems for C-RAN [13–16]. To cope with the increasing traffic demands and the traffic variation, Zhu et al. [13] proposed an interference-aware resource allocation scheme in C-RAN by mapping the BBU to RRH with the consideration of the dynamic downlink (DL) and uplink (UL) reconfiguration. To deal with the interference within three neighboring cells between RRH-to-RRH, Cao et al. [14] studied the interference between alignment transceivers under the TDD-based C-RAN. The simulation result verifies that this scheme is useful when there are strong inter-cell interference between RRHs. To effectively saving energy, Liu et al. [15] proposed a re-configurable backhaul for OFDMA-based C-RAN systems using radio-over-fiber (RoF) technology. This work shows its benefits in both of performance