ISSN 1996-3343

Asian Journal of Applied Sciences

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OPEN ACCESS Asian Journal of Applied Sciences

ISSN 1996-3343
DOI: 10.3923/ajaps.2017.179.185

Research Article
Call Admission Control Algorithm for Energy Saving in 5G H-CRAN Networks

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Abstract
Objective: This study proposed a call admission control (CAC) algorithm focused on the remote radio heads (RRHs) in order to further reduce the power consumed by the H-CRAN by switching into sleep mode, the under-used RRHs. **Methodology:** Heterogeneous-Cloud Radio Access Networks (H-CRAN) were considered by many experts as a key technology that can meet the challenges in terms of throughput, power reduction and latency of 5G networks. It was an architecture that combines the advantages of heterogeneous networks (HetNets) and C-RAN networks. It was, therefore, rightly considered as a promising solution for increasing the spectral efficiency and energy efficiency of 5G networks. **Results:** It was performed that simulations of algorithm into two contexts depending on the cell radius: In the context 1, the radius is 1 km and 0.5 km in the second context. The simulations show that, more the radius is lower, more the algorithm reduced the power consumption with rates between 61 and 77% and then multiplied the energy efficiency by a ratio of 3. **Conclusion:** C-RAN networks offered the advantage of energy reduction and BBU can manage many RRHs. The future research will test this algorithm in a context where the UEs are in mobility situations and taking into account the effect of interferences.

Key words: 5G, H-CRAN, remote radio heads, call admission control, heterogeneous networks, sleep mode

Citation: Raymond Gbegbe, Olivier Asseu, K. Eugene Ali, Guy L. Diety and Soumaya Hamouda, 2017. Call admission control algorithm for energy saving in 5G H-CRAN networks. Asian J. Applied Sci., 10: 179-185.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In recent years, the IP traffic has grown exponentially. To provide a level of QoS satisfying their customers, the current mobile operators are expanding their radio access network. But this expansion increases the operating and maintenance costs (OPEX, CAPEX) and energy consumption. The next generation mobile network, the 5G planned to be launch in 2020, was expected to deliver data rates of 10-100 times compared to the 4G network and an energy consumption reduction around 90%[1,2]. Several recent studies have shown that the heterogeneous C-RAN (H-CRAN) could be the architecture to meet the challenges and to enhance the performance of 5G[3-5]. It was a combined architecture of HetNet network and C-RAN network. HetNets consist of integrating many low power nodes (LPNs) or small cells (micro, pico or femto cells) inside macro-cells or HPNs (high power nodes). This increases network coverage and user throughput. As for C-RAN, it was a centralized architecture in which the part responsible for the baseband processing and was separated from the part responsible for basic radiofrequency processing of the base stations (BS)[5]. The baseband processing was performed by BBUs (base band unit) which were located together on a centralized site called BBU Pool, to better manage resource allocation and interferences mitigation. The radio frequency processing was done by remote radio heads (RRH: remote radio head). Beyond efficient resource management, the centralization of BBUs can reduce the energy costs of air conditioning[4].

In H-CRANs the macro BS (MBS or M-RRH) is responsible for signalling control, while the RRHs are responsible for the transmission of high-speed data to the users. Several studies in the industrial and academic domains are working to optimize the use of spectrum and energy in H-CRANs. Among these works could cite the so-called "clustering" techniques which aim to determine the best BBU-RRH association in order to minimize the number of RRHs allocated to a data stream or to maximize the number of RRHs by BBU[6-8]. By reducing the number of active BBUs or RRHs, clustering mechanisms reduce the energy consumption of the system. On the other hand, some research's works focuses on methods of switching into sleep mode BBUs or RRHs to increase the energy efficiency[9]. For example, Zuo *et al.*[10] study a joint mechanism for RRHs activation, a best UE-RRH association and resources allocation to maximize energy efficiency H-CRANs. Other studies focused on algorithms whose aim was to minimize both the total power consumed and the number of switching of ON/OFF modes in a H-CRAN network with QoS guarantee[11,12].

This article uses an algorithm in order to minimize the total power consumption in the H-CRAN. The principle was to switch in sleep mode, the RRHs which are underused, that is to say the RRHs whose total power emitted was below a certain threshold of power. The UEs associated with these RRHs will then be reallocated to the other RRHs that are not saturated and underused. The simulations were carried out in 2 contexts: In the first one it was considered a macro cell of radius of 1 km and in the 2nd the radius of the cell is 0.5 km. It was then analyzed the evolution of the total power consumed by the network as a function of the number of RRHs in the cell.

MATERIALS AND METHODS

This research project, conducted in the Laboratory of Applied Electrical and Electronic (INPHB Yamoussoukro, Côte d'Ivoire) from May, 2016-June, 2017 by a theoretical study, has been confirmed by simulations results on a system model of an H-CRAN network.

System model: This system model is an H-CRAN network consisting of a set of BBUs located in a BBU Pool and macro cells within which macro RRH or HPN (high power node) and RRHs or LPNs (low power node) are available. Each macro cell was composed of a macro BS or macro RRH responsible for signalling and a set of micro, pico or femto RRHs that are responsible for the transmission of user data. The RRHs are randomly distributed inside the macro cell. The macro BS macro can also transmit useful data when the RRHs are saturated.

The following sections, focus only on the power consumed by the set of RRHs of a single macro cell as illustrated in Fig. 1. From now, it was assumed that the latency induced by the fronthaul network is null.

Energy model of base stations: It was assumed that the macro cell was composed of a number M of RRHs: A macro BS or macro RRH and (M-1) RRHs of the "small cell" type. The variables P_{MBS} or P_{M_RRH} are defined as the power consumed by the macro BS or M-RRH and P_{RRHm} defined the power consumed by the RRH number m of the microcell. The binary variables β_m and λ are defined, respectively as the RRH_m activation variable and the macro BS activation variable, that means that:

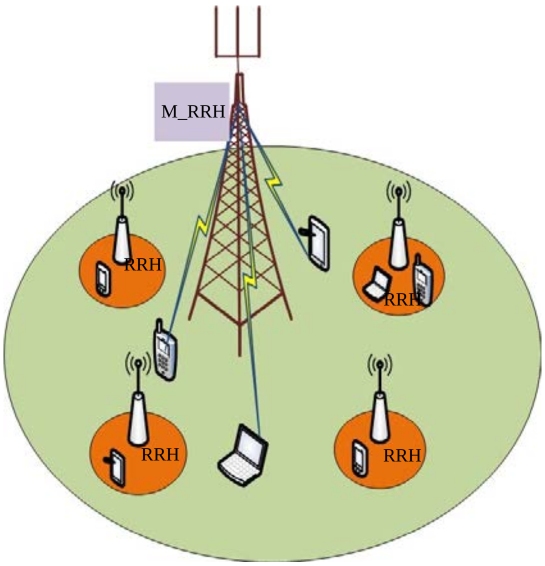

Fig. 1: H-CRAN Architecture

$$\beta_m = \begin{cases} 1 \text{ if the } RRH_m \text{ is ON} \\ 0 \text{ if the } RRH_m \text{ is OFF} \end{cases} \quad (1)$$

$$\lambda = \begin{cases} 1 \text{ if the } RRH_m \text{ is ON} \\ 0 \text{ if the } RRH_m \text{ is OFF} \end{cases} \quad (2)$$

In a similar way for UEk association with a BS the binary variable a_{mk} is equal to 1 when the UEk was served by the RRH_m and 0 otherwise. At th end b_k is the binary variable indicating the attachment of the UEk to the macro BS.

The power consumption of the RRH_m in the macro cell is modelized as below:

$$P_{RRH,m} = \begin{cases} P_m + P_{CC,m} \text{ if the } RRH_m \text{ is active} \\ P_{0,stat} \text{ if the } RRH_m \text{ is in sleep mode} \end{cases} \quad (3)$$

where, $P_{CC,m}$ is the static power of RRH_m when it was active and P_m is the sum of the powers supplied to the UEs served by the RRH_m:

$$P_m = \sum_{k=1}^{K} a_{mk} P_{mk}$$

P_{mk} is the power transmitted by the RRH_m to the UEk. It is thus deduced that:

$$P_{RRH,m} = \beta_m \left(P_{CC,m} + \sum_{k=1}^{K} a_{mk} P_{mk} \right) + (1-\beta_m) P_{0,stat} \quad (4)$$

Similarly, the energy consumption model of the macro MBS or M_{RRHm}, can be defined as follows:

$$P_{MBS} = \begin{cases} P_{MBS} + P_{CC,BS} \text{ if the MBS is active} \\ P_{BS,stat} \text{ if the MBS is in sleep mode} \end{cases} \quad (5)$$

With $P_{CC,MBS}$ the static power of the MBS when it was active and P_{MBS} is the sum of the powers supplied to the UEs served by the MBS:

$$P_{MBS} = \sum_{k=1}^{K} b_k P_{BS,k}$$

$P_{MBS,K}$ define transmitted by the MBS to the UEk. Therefore, the power consumed by the MBS can be defined as follows:

$$P_{MBS} = \lambda \left(P_{CC,MBS} + \sum_{k=1}^{K} b_k P_{MBS,k} \right) + (1-\lambda) P_{MBS,stat} \quad (6)$$

For each macro cell, the total power consumed is therefore:

$$P_T = PMBS + \sum_{m=1}^{M-1} P_{RRH,m} = P_{M\_RRH} + \sum_{m=1}^{M-1} P_{RRH,m} \quad (7)$$

Problem formulation:

$$PT = \lambda \left(P_{CC,MBS} + \sum_{k=1}^{K} b_k P_{M_{RRH}}, k \right) + \sum_{m=1}^{M-1} \beta_m \left(P_{CC,m} + \sum_{k=1}^{K} a_{mk} P_{mk} \right) \quad (8)$$

Minimize

Under constraints:

$$\sum_{k=1}^{K} a_{mk} P_{mk} \leq P_{RRH\_max}, \forall m < M$$

$$\sum_{k=1}^{K} a_{mk} P_{mk} \geq P_{RRH\_seuil}, \forall m < M$$

$$\sum_{k=1}^{K} b_k P_{MBS,k} \leq P_{MBS\_max}$$

$$\sum_{k=1}^{K} b_k P_{MBS,k} \geq P_{MBS\_seuil}$$

Calculation of the required power of an RRH to guarantee the user bit rate: In this study scenario, it was assumed that each UE receives the minimum bit rate satisfying its QoS. According to Shannon's formula:

Table 1: Simulation parameters and their meaning

Parameters	Meaning	Values
M	Number of RRHs per macro cell	Variable
K	Number of UEs per macro cell	Variable
$P_{RRH-max}$	Maximum power of a small RRH	200 mw
$P_{MBS-max}$	Maximum power of a macro RRH	20 W
$P_{RRH-seuil}$	Minimum power threshold for a small RRH	0<threshold<1
$P_{MBS-seuil}$	Minimum power threshold for a macro RRH	0<threshold<1
P_{CC-m}	Constant power corresponding to the power consumed by the RRH circuits	20% $P_{RRH-max}$
P_{CC-MBS}	Constant power corresponding to the power consumed by the macro RRH circuits	20% $P_{MBS-max}$
N_0	Noise spectral density	-174 dbm/hz
L_{mk}	Path loss between the RRHm and the UEk	130.62+37.6 log10(dmk) Dmk = distance (RRHm, UEK)
$R_{min,k}$	Minimum bit rate required by an EU for a service, assumed to be constant for all UEs	2 Mbps

$$R_{mk} = W_k.\log_2\left(1+\frac{P_{mk}.g_{mk}}{N_o W_k + \sum_{i\neq m}^{I} P_{ik}.g_{ik}}\right)$$

with

W_k = The band with of an UE_k,

P_{mk} = Power transmit by RRHm to the UEk

g_{mk} = The channel gain

N = Noise spectral density

$\sum_{i\neq m}^{I} P_{ik}.g_{ik}$ = Co-channel interference

I = The number of interfering stations

It is assumed that $W_k = W_{PRB}$ = 180 KhZ, the bandwidth of an OFDM resource block in LTE. Co-channel interference was neglected in this studies scenario. To guarantee the QoS must have:

$$R_{min,k} = W_{PRB}.\log_2\left(1+\frac{P_{mk}.g_{mk}}{N_0 W_{PRB}}\right)$$

$$\frac{R_{min,k}}{W_{PRB}} = \log_2\left(1+\frac{P_{mk}.g_{mk}}{N_0 W_{PRB}}\right)$$

From this deduce that:

$$P_{mk} = \left(\frac{R_{min,k}}{2W_{PRB}} - 1\right).\frac{N_0 W_{PRB}}{g_{mk}}$$

$$P_{mk} = \left(\frac{R_{min,k}}{2W_{PRB}} - 1\right).N_0 W_{PRB}.L_{mk} \quad (9)$$

where, $L_{mk} = 1/g_{mk}$ path loss between RRHm and UEk.

Formulation of the optimization problem:

$$P_T = \lambda_q\left(P_{CC,MBS} + \sum_{k=1}^{K} b_{qk} P_{M_{RRH},k}\right) + \sum_{m=1}^{M-1} \beta_m\left(P_{CC,m} + \sum_{k=1}^{K} a_{mk} P_{mk}\right) \quad (10)$$

Minimize:

Under constraints

$$\sum_{k=1}^{K} a_{mk} P_{mk} \leq P_{RRH\_max}, \forall m < M$$

$$\sum_{k=1}^{K} a_{mk} P_{mk} \geq P_{RRH\_seuil}, \forall m < M$$

$$\sum_{k=1}^{K} b_k P_{MBS,k} \leq P_{MBS\_max}$$

$$\sum_{k=1}^{K} b_k P_{BS,k} \leq P_{MBS\_seuil}$$

The power $P_{M\_RRH,k}$ is calculated in a similar way to (9):

$$P_{M\_RRH,k} = \left(\frac{P_{min,k}}{2W_{PRB}} - 1\right).N_0 W_{PRB}.L_{M\_RRH,k} \quad (11)$$

$L_{M\_RRH,k}$ = Path loss between the M_{RRH} and the UEk

According to this algorithm assumed that the consumption of a RRH in sleep mode is null:

$$P_{0,stat} = P_{BS,stat} = 0$$

Simulation parameters: In this simulation scenario, it was considered an H-CRAN architecture composed of a macro cell, consisting of M RRHs including a macro BS or macro RRH and (M-1) RRHs. The Table 1 below details the meaning of the simulation parameters and their values.

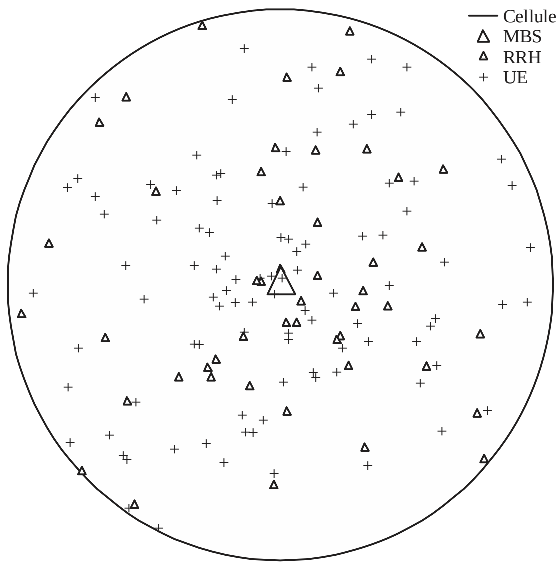

Fig. 2: Distribution of the UEs in the cell

Functions to be simulated: In this study the evolution of the total power consumed by the system as a function of the number of RRHs: P_{TR} = f (number_RRH).

It is assumed that the UEs are randomly distributed throughout the cell as shown in Fig. 2.

RESULTS AND DISCUSSION

Description of the algorithm: This study algorithm consists of 2 main functions:

F1: Allocation by standard CAC
F2: Allocation by CAC taking into account a power threshold

An RRH may be considered to designate a small RRH or the macro RRH.

F1 description:

- For each UEk, calculate the power provided by each RRH (small or macro cell) present to reach the throughput which guarantees the QoS
- Sort the P_{mk} in ascending order, the first choice of the UEk is the RRH which provides the lowest power and so on
- Assign UEk to its first choice
- For each RRH calculate $P_{RRH} = \Sigma P_{UEk,1}$ where $P_{URk,1}$ is the power provided by the first choice RRH of UEk
- As long as there is an RRH for which $P_{RRH}>P_{max}$, then, step A
- At the end of this loop, calculated $P_{F1tot} = \Sigma P_{RRH}$ which is the power consumed in a conventional CAC

F2 description:

- At the end of function F2, it was checked whether there were RRHs whose power was below a threshold power
- If $P_{RRH}<P_{threshold}$ forsRRHs, then proceed to step B
- End of the algorithm when there was no more redirection: calculated the total power: $P_{F2tot} = \Sigma P_{RRH}$ always active, which corresponds to the power optimized by this algorithm,

Comparison of $P_{F1tot} = \Sigma P_{RRH}$ and P_{F2tot} = always active

Step A: Redirection of all the most costly UEs in terms of powers, for the RRH to their next choice until $P_{RRH} \leq P_{max}$, always making sure that each redirection have $P_{RRH\_host} \leq P_{max}$, where P_{RRH_host} is the power of the host RRH

Step B: Redirection of all UEs served by the RRH to their next choice, making sure that during each redirection $P_{RRH\_host} \leq P_{max}$, for the host RRH
The underused RRH (original RRH) was switched to sleep mode

Simulation results: This section presented the results of the simulations that were carried out according to the 2 contexts, in context 1, the radius of the cell is 1 km and in the context 2, the radius is fixed at 0.5 km. In each context, it was represented the evolution of the total power as a function of the number of RRHs: P_{TR} = f(number_RRH). In this program, the snapshots average was set at 500 in order to represent the function P_{TR} = f(number_RRH). It was assumed that the values of the simulation parameters were as follows: power threshold=0.5, K=150 UEs and each UE throughput was set at 2 Mbps.

Figure 3 shows that for a given number of UEs and a given power threshold the power P_{TR} = f(number_RRH) was substantially identical according to the 2 CAC algorithms in the context 1, up to 25 RRHs. When the number of RRHs varies between 25 and 55 CAC algorithm consumes slightly compared to the classic CAC. Between 65 and 105 RRHs this algorithm reduces the power consumed by a rate between 7.09 and 52%.

Moreover, in the context 2, the power P_{TR} = f(number_RRH) was always higher for the standard CAC compared to the CAC with threshold, especially when the number of RRH reaches 15, the power of the conventional CAC varies between 5.79 and 9.27 W. On the other hand, for the CAC with threshold, before 15 RRHs, this study algorithm consumes practically the same power as

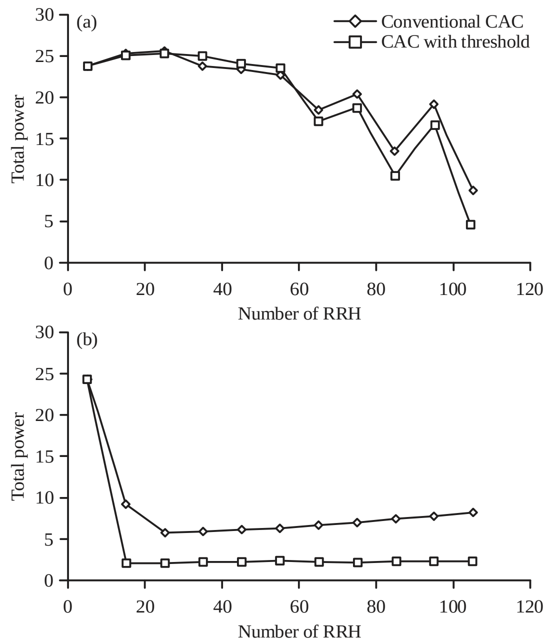

Fig. 3: The results of simulations

the conventional CAC, it can be seen from the Fig. 3 that for a number of 5 RRHs the powers consumed are substantially identical because all the resources are almost used.

From 15 RRHs, the power consumption varies between approximately 2.10 and 2.3 W. This represents a reduction rate varying between 61.57 and 77.32%. Therefore more the radius of the cell was lower, more the power consumed by the network decreases as just showed through algorithm. And in addition, for a small radius CAC algorithm with threshold, considerably reduces the power consumed by the system in comparison with conventional CAC in C-RAN network. For example Xu and Wang[7] developed an algorithm in C-RAN network, which reduced the power consumed by a rate between 27 and 53%. That was the same observation for the study of Zhao *et al.*[13]. This therefore proved that this study algorithm improves the energy efficiency: it can seen that from 15 RRHs the EE is multiplied on average by 3. It was quite normal, when the number of resources increases for a fixed number of UEs, the number of under-utilized RRHs increases. Therefore, this algorithm could pause a higher number of RRHs. Moreover, the secondary choices (RRHs) of the UEs which were redirected are more likely to be close to the UEs, radiating powers with low powers since in context 2, the density of RRHs km^{-2} is multiplied by 4 compared to the context 1.

CONCLUSION

This study was proposed to design call admission control (CAC) algorithm to reduce power consumption in a 5G H-CRAN network. In this study defined an algorithm that switches in sleep mode all RRHs whose radiated power is below a power threshold that we have set and then analyzed the evolution of the total power in two cell-dependent contexts with a random distribution throughout the cell. Context 2 multiplies averagely EE by 3 and reduces the power between 61 and 73%. So, when the cell radius is lower and more the EE increases in general, but even more with our CAC algorithm.

In the future research will test this algorithm in a context where the UEs are in mobility situations and taking into account the effect of interferences.

SIGNIFICANCE STATEMENTS

This study proposed for the first time a call admission control (CAC) algorithm that is focused on the radio remote heads (RRHs). C-RAN networks offer the advantage of energy reduction, since a BBU can manage many RRHs.

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