

Energy Efficiency Enhancement in 5G Heterogeneous Cellular Networks Using System Throughput Based Sleep Control Scheme

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Abstract— Currently, Cellular architectures are designed with an efficient providing infrastructure is one of the critical challenges in 5G dense heterogeneous cellular networks (HetNets). By adding many small base stations (SBSs) in a macro base station (MBS) is one way to support the rapid growth of mobile data communication, high data rate services and to provide continuous coverage. The high number of network elements leads to a significant increase in power consumption. To solve the problem, the SBS on/off algorithm has been introduced to reduce power consumption but also reduced energy efficiency as we called the conventional schemes. This paper we proposed as the SBS switching to sleep state algorithm based on the system throughput (MBS cell throughput and SBS cell throughput) is used the decision criteria for SBS to be in the sleep state. The simulation results, The proposed scheme can reduce the total power consumption of the network and enhance energy efficiency more than the conventional schemes.

Keywords— Small cell, Sleep control, Energy efficiency, Power consumption, System throughput, 5G, Heterogeneous cellular network.

I. INTRODUCTION

There is currently research available around the world to develop the next generation. It is expected that the 5G network will support large amounts of mobile data and wireless connections and will reduce costs and improve energy efficiency, including quality of service (QoS). For this reason, 5G wireless networks should take advantage of the potential of new developments, including the deployment of advanced and heterogeneous deployment of cells and massive antenna arrays, such as massive multi-input (mMIMO) technology, using a higher frequency, and especially millimeter wave (mmWave) [1].

To achieve the mass data capacity, the heterogeneous network (HetNet) arises at the moment. The small cell stations (SBSs) provide a fast, flexible, cost-efficient, and customer need oriented solution for cellular service providers. The term SBS refers to low-powered radio access nodes that have a transmission range of several tens to several hundreds of meters. The SBSs will offload users from the congested macro base

station (MBSs) to enhance their quality of service (QoS) and improve the overall system capacity. The relatively smaller link distance in SBSs, as well as the smaller number of users served by each SBS, are expected to enhance user QoS in terms of outage and throughput. SBSs include femtocells, picocells, and microcells. A multitier network where SBSs are overlaid on MBSs is generally referred to as a heterogeneous network (HetNet) [2].

Among several challenges, power consumption will be a critical consideration in the 5G generation. By adding many small base stations. The high number of network elements leads to a significant increase in power consumption. To solve the problem, the SBS sleep control algorithm has been introduced to reduce power consumption.

The rest of this paper is organized as follows: We present related work to the conventional sleep control scheme in Section II. Section III describes the proposed system throughput based sleep control scheme. In Section IV, we present our simulation system model and schemes under comparison. Simulation results are shown in Section V. Finally, conclusions are presented in Section IV.

II. RELATED WORK

The conventional sleep control scheme is shown in the orange border in figure 1, the number of user equipment (UEs) connect to that small base station (SBS) is used decision criteria to change the state from active to sleep state to reducing power consumption. The basis of this decision criteria has the following methods [3]:

- Count the number of UEs connect to each SBS N_{con}^i
- Define the number of UEs connect to SBS as Sleep Threshold N_{sleep} (Decision criteria)
- If the number of UEs connected to each SBS N_{con}^i is less than or equal to the number of UE sleep threshold N_{sleep} [3].

$$\begin{cases} N_{con}^i \leq N_{sleep}; & \text{For sleep state} \\ N_{con}^i > N_{sleep}; & \text{For active state} \end{cases} \quad (1)$$

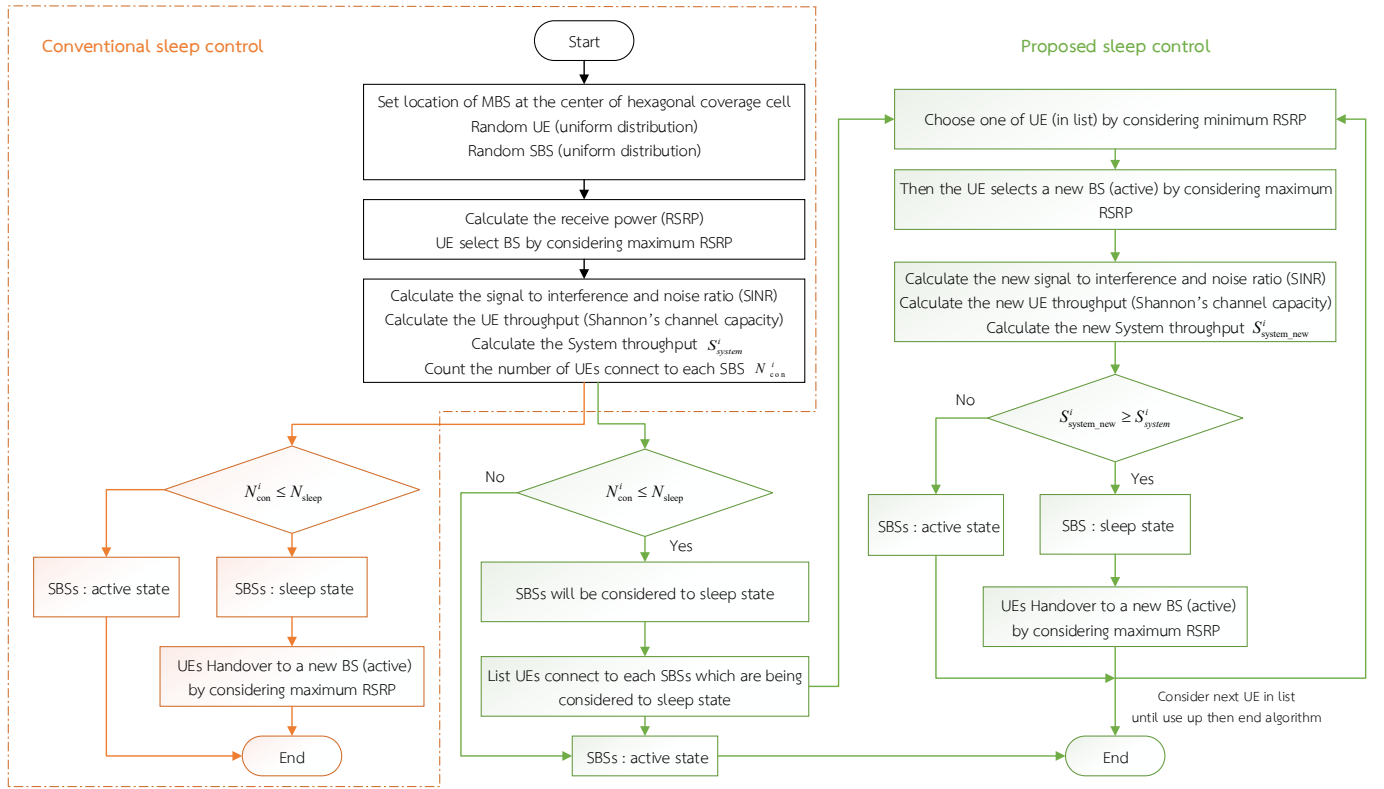


Figure 1. The flowchart of the conventional and the proposed schemes.

- The SBSs change state from active to sleep state
- UEs Handover to a new BS (active state) by considering maximum RSRP

Although this conventional sleep control scheme can reduce the total power consumption of the network, but energy efficiency (EE) has decreased significantly because some SBSs may have a higher data rate or throughput while the number of UEs connected to that SBS is less than or equal to a sleep threshold N_{sleep} , then that SBS being changed into sleep state.

Causing the system throughput to decrease but also reduce energy efficiency.

Accordingly, the conventional sleep control scheme can complete lower power consumption but also reduce system throughput and energy efficiency, respectively. From the above problem, the decision criteria need a new consideration for sleep control of the SBSs.

III. SYSTEM THROUGHPUT BASED SLEEP CONTROL SCHEME.

The step of system throughput based sleep control scheme by using the system throughput the decision criteria for SBS to be in a sleep state in HetNets as shown in the condition (2) and figure 1. shows the proposed sleep control and described as follows:

- 1st step: Set location of MBS at the center of hexagonal coverage cell, Random UE (uniform distribution), Random SBS (uniform distribution)
- 2nd step: Calculate the receiving power (RSRP), UE select BS by considering maximum RSRP

- 3rd step: Calculate the signal to interference and noise ratio (SINR), Calculate the UE throughput (Shannon's channel capacity), Calculate the System throughput S_{system}^i , Count the number of UEs connect to each SBS N_{con}^i
- 4th step: If the number of UEs connected to each SBS N_{con}^i is less than or equal to the number of UE sleep threshold N_{sleep}
- 5th step: SBSs will be considered to sleep state (if not, remain to active state)
- 6th step: List UEs connect to each SBSs which are being considered to sleep state
- 7th step: Choose one of UE (in the list) by considering minimum RSRP
- 8th step: UE selects a new BS (active) by considering maximum RSRP
- 9th step: Calculate the new signal to interference and noise ratio (SINR), Calculate the new UE throughput (Shannon's channel capacity), Calculate the new System throughput $S_{system_new}^i$
- 10th step: If the new System throughput $S_{system_new}^i$ (from 9th step) is more than or equal to current System throughput S_{system}^i (from 3rd step)

$$\begin{cases} S_{system_new}^i \geq S_{system}^i & \text{For sleep state} \\ S_{system_new}^i < S_{system}^i & \text{For active state} \end{cases} \quad (2)$$

- 11th step: The SBS change state from active to sleep state (if not, remain to active state)
- 12th step: UEs Handover to a new BS (active) by considering maximum RSRP
- 13th step: back to 7th step again, then consider next UE in list

IV. SIMULATION MODEL

A. System Model

The system model is a dense heterogeneous network that consists of both macro base stations (MBS) and small base stations (SBSs) which all SBSs are located within the coverage area of the MBS. The MBS is located at the center of the network with a hexagonal coverage cell. The coverage cell radius of the MBS is 500 meters. The number of UE (N_{UE}) is 50 UEs and located are distributed uniformly in hexagonal coverage area. The UEs are assigned in stationary point without mobility. The number of SBS (N_{SB}) is 5-50 cells and located are distributed uniformly, as shown in figure 2.

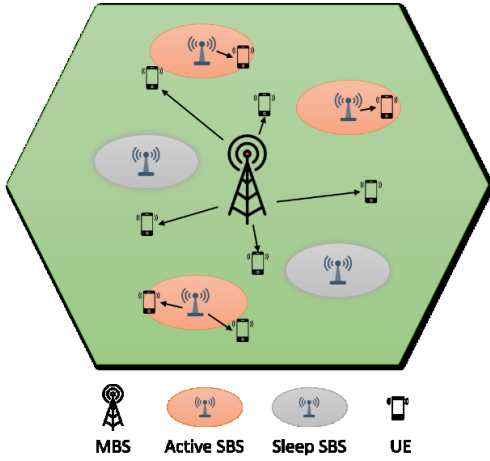


Figure 2. System model under consideration.

The radio access technique is orthogonal frequency division multiple accesses (OFDMA) in which MBS or SBS allows the same amount of the frequency resource to the connected UEs by dividing the total frequency bandwidth (MHz) equally. The co-channel interference is only assumed between the same types of base stations because we used the different carrier frequency bands between the MBS and the SBS. The data traffic model is a full buffer. In the propagation model, the path loss due to the distance attenuation, and shadow fading attenuation are assumed. Therefore, received signal power P_{rx}^j at the j -th UE connected to the i -th base station can be expressed by [4];

$$P_{rx}^j = P_{tx}^i - (PL^j + \psi^j) \quad (3)$$

where P_{tx}^i is transmission power at the i -th base station, ψ^j is the shadow fading attenuation at the j -th UE, which follows a log-normal distribution, and PL^j is the path loss due to the distance attenuation from the connecting base station to j -th UE.

Here, the path loss PL^j in (3) is modeled by the OkumuraHata model. The path loss PL_{MB}^j for MBSs can be given by [4];

$$PL_{MB}^j = 128.1 + 37.6 \log R^j \quad (4)$$

where R^j is the distance from the connecting base station to the j -th UE, and the path loss PL_{SB}^j for SBSs can be given by [4];

$$PL_{SB}^j = 140.7 + 36.7 \log R^j \quad (5)$$

As for the SINR at the j -th UE, the $SINR_{UE}^j$ can be expressed by [4];

$$SINR_{UE}^j = \frac{P_{rx}^j}{I^j + N_0 B_{UE}^j} \quad (6)$$

where N_0 is the noise power density, and I^j is the co-channel interference at the j -th UE from other active base stations except its owner connecting base station, which is represented by [4];

$$I^j = \sum_{\substack{n=1 \\ n \neq j}}^N P_{rx}^n \quad (7)$$

where N is the number of active base stations generating the interference, and P_{rx}^n is the received power from the n -th interfering base station.

$$S_{UE}^j = B_{UE}^j \log_2(1 + SINR_{UE}^j) \quad (8)$$

UE throughput S_{UE}^j in (8) [4] is calculated by Shannon's channel capacity theory, the $SINR_{UE}^j$ in (6) and B_{UE}^j is the frequency bandwidth allocated to the j -th UE

The total power consumption P_{Total} , which is given by $P_{Active-MBS}$ at the MBS is assumed to be constant and always active and that at the SBS is assumed to be different depending on its operating state: the power consumption of active state is $P_{Active-SBS}$, not active (There is no UE connect) is $P_{Not-Active-SBS}$ and the sleep state P_{SL-SBS} . Hence, the total power consumption can be expressed by [4];

$$P_{Total} = P_{Active-MBS} + N_{Active-SBS} \cdot P_{Active-SBS} + N_{Not-Active-SBS} \cdot P_{Not-Active-SBS} + N_{SL-SBS} \cdot P_{SL-SBS} \quad (9)$$

where the number of active MBS is only one station, $N_{Active-SBS}$, $N_{Not-Active-SBS}$, N_{SL-SBS} are the number of SBSs in the active state, the not active state and the sleep state, respectively.

S_{cell}^i is current cell throughput at the i -th SBS obtained by summation of the user throughput S_{UE}^i , which can be expressed by [4];

$$S_{\text{cell}}^i = \sum_{j=1}^{N_{\text{con}}^i} S_{\text{UE}}^j = \sum_{j=1}^{N_{\text{con}}^i} \{B_{\text{UE}}^j \log_2(1 + \text{SINR}_{\text{UE}}^j)\} \quad (10)$$

S_{sys} is the system throughput, which is given by the summation of cell throughput for MBS and SBSs in HetNets. The S_{sys} can be expressed by [4];

$$S_{\text{sys}} = \sum_{i=1}^{N_{\text{MBS}}} S_{\text{MBS}}^i + \sum_{i=1}^{N_{\text{SBS}}} S_{\text{SBS}}^i \quad (11)$$

The energy efficiency EE is defined by system throughput S_{sys} in (11) per total power consumption P_{Total} in the system in (9), which can be expressed by [4];

$$EE = \frac{S_{\text{sys}}}{P_{\text{Total}}} \quad (12)$$

B. Schemes Under Comparison

To simplify comparison and analysis, we make three schemes as followings:

- Without sleep control: All SBS remain active in the network without the sleep control scheme
- Conventional sleep control scheme as described in section II
- System throughput based sleep control scheme is the proposed scheme as defined in section III

V. SIMULATION RESULTS

In this paper, we show the simulation results of our proposed system throughput based sleep control scheme compared with the conventional sleep control scheme and without sleep control scheme in terms of system throughput S_{sys} , total power consumption P_{Total} , and energy efficiency EE .

The detailed simulation parameters of MBS and SBS are the same as [5] and summarized in Table 1

TABLE 1. CALCULATION PARAMETERS

Parameters	Value
Cell radius	500 m
No. of user equipment (UEs)	100
No. of MBS	1
No. of SBS	5-50
Bandwidth of MBS and SBS	20 MHz
Carrier frequency of MBS	2.5 GHz
Carrier frequency of SBS	3.5 GHz
Transmit power of MBS	43 dBm
Transmit power of SBS	30 dBm
Path-loss models of MBS	$PL_{\text{MBS}} = 128.1 + 37.6 \log_{10} R$
Path-loss models of SBS	$PL_{\text{SBS}} = 140.7 + 36.7 \log_{10} R$
$P_{\text{Active-MBS}}$	150W
$P_{\text{Active-SBS}}$	30W
$P_{\text{Not-Active-SBS}}$	25W
$P_{\text{SL-SBS}}$	15W
Noise power density	-174 dBm/Hz

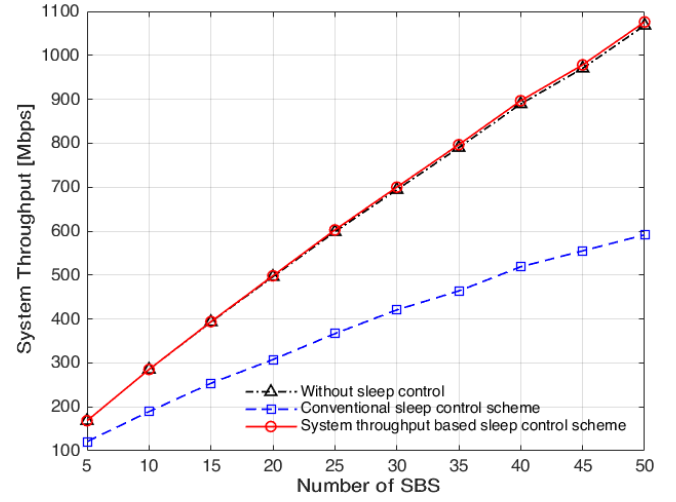


Figure 3. The system throughput versus different the number of SBSs.

Figure 3 shows the system throughput S_{sys} versus a different number of SBSs between three schemes. From the figure, it can be observed that the system throughput with a sleep control scheme provides the highest system throughput. This is because the proposed algorithm calculated the system throughput as decision criteria if the new system throughput is more than or equal to old system throughput. The SBSs change the state from active to sleep state (if not, remain active state) as in (2)

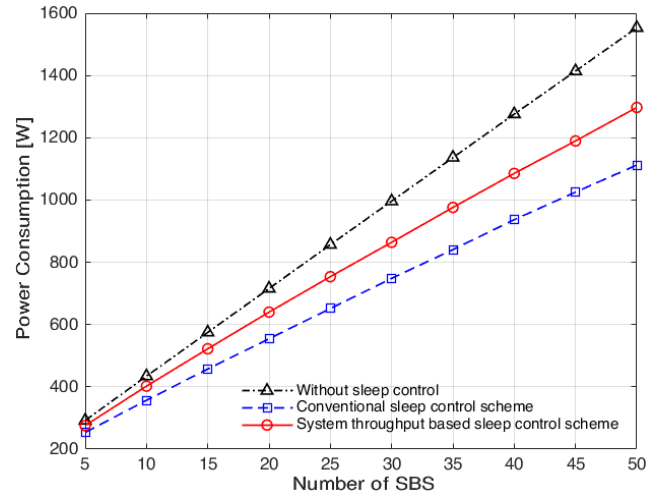


Figure 4. The power consumption versus different the number of SBSs.

Figure 4 shows the total power consumption P_{Total} versus a different number of SBSs between three schemes. In the figure, the power consumption for without sleep control has the highest power consumption due to all the SBSs keep in the active state. From the figure, it can also be observed that the proposed sleep control scheme reduces power consumption but still remain higher than the conventional sleep control scheme. Because some of the SBSs are slept when the number of UEs connected to the SBS is less than or equal to the sleep threshold level as in

(1) but need to consider the system throughput before changing the state.

Figures 3 and 4, which are not our strategy to reduce the least power consumption and increase the highest system throughput, respectively. But our strategy will enhance the highest energy efficiency from a comparison between power consumption and system throughput in the form of EE equation (12) on the next figure.

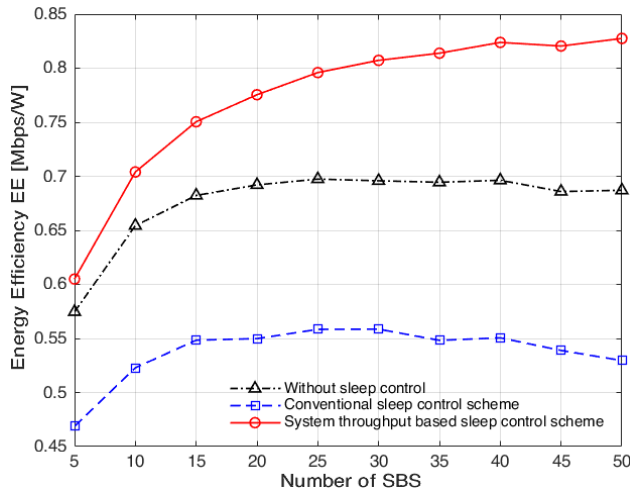


Figure 5. The energy efficiency versus different the number of SBSs.

A comparison of energy efficiency versus a different number of SBSs between the three schemes is illustrated in figure 6. It can be observed that the proposed sleep control scheme can achieve better energy efficiency than the conventional sleep control scheme and without the sleep control scheme for all the numbers of the SBSs.

VI. CONCLUSIONS

In this paper, we presented the system throughput S_{sys} , total power consumption P_{Total} , and energy efficiency EE in dense 5G HetNets. We proposed the solution of the SBS switching to sleep state algorithm based on the system throughput is used the decision criteria for SBS to be in the sleep state.

From the computer simulation result, this paper shows that the proposed sleep control scheme is not only reducing the total power consumption but also enhance the energy efficiency of the network when compared with the conventional schemes and without the sleep control scheme.

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