An improved approach for managing energy efficiency in mobile networks

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Article Info

ABSTRACT

It is highly expected that soon there will be environmental and economic negative implications from the amount of energy consumed by wireless network devices. Therefore, many researchers have paid attention toward addressing these challenges to investigate the impact of these wireless networks on both environment and the economy. This paper proposes an approach for alternating work among the fifth generation (5G) with long-term evolution (LTE) wireless networks. The idea of the proposed approach relies on turning off specific base stations (BSs) and antennas for the users based on the required quality of service (QoS). Some BSs like 5G networks aim to provide high-speed communications with significant savings in energy consumption during high traffic periods. On the other hand, there is a slow speed with the high consumption of energy in other BSs like LTE networks. Our proposed solution employs the idea of activating some of the BSs networks and changing the number of active antennas that achieves optimal results for the entire area. Doing so lead to a significant reduction in energy consumption when the traffic load is low. The experimental results illustrate that our proposed solution outperforms the most recent approaches by saving a significant amount in power consumption while maintaining a stable service awareness during switching situations.

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1. INTRODUCTION

Technological advancements have helped to improve economic growth and human lives for modern societies in recent years, with cellular networks being one of the most notable examples. The growth of cellular networks, which offer incredible video streaming data, is rapidly increasing the number of mobile phone subscribers [1]. It has been reported that between the years 2017 and 2018, mobile memberships increased by up to 3%, reaching a total of 7.9 billion users in the 3rd quarter of the year 2018. It has also been reported that the utilization of the mobile data traffic has been increased to 79%, reaching 20.7 ExaBytes (EB) per month in the same period (the 3rd quarter of 2018) [2]. Furthermore, due to the ongoing cellular network development that led to the invention of the 5G cellular networks, and the introduction of the internet of things (IoT), which is considered the basis of emerging applications; the number of mobile subscribers grows exponentially, advancing telecommunications to improve quality of life and grow the

global economy [3]. It is anticipated that the number of mobile subscribers could reach 8.9 billion users by the year 2024. It is also expected that the connections of the cellular IoT will exceed 4.1 billion devices. Due to this tremendous increment in the number of mobile users and the number of IoT devices, it is anticipated that the usage of mobile data traffic will also increase to 136 EB every month. It is also expected that the majority of the data traffic comes from video streaming which can take up to 74% of total network traffic. In addition, it is also expected that the 5G networks will be very crucial and used to transport up to 25% of the total mobile data traffic in the world [4]. This is due to the fact that 5G networks are no longer limited to being used for personal mobile services but can also be used for data communications in large computer machines. Therefore, 5G is expected to alleviate some of the most crucial network challenges [5].

A recent experimental research study reported in [3] found that the base stations (BSs) consume up to 80% of the energy necessary when operating the cellular networks [3]. As a result, it seems that increasing the energy efficiency (EE) is very crucial and has a positive influence on the network's EE. Thus, the issue of the circuit power consumption by the BS should not be neglected. Apparently, for several decades, wireless network systems have been developed to maximize the performance of the network when it is loaded with uniform and heavy network traffic. Nevertheless, in real-world scenarios, network traffic at various locations keep fluctuating at a different period during the day. Hence, this implies that a portion of certain BSs which are under low network traffic load can be turned off. Furthermore, the number of active antennas at the BS could be decreased as well to save a significant amount of energy.

The works proposed in [6]–[10] aim at designing and building several active antennas at the BS, with certain radio frequency (RF) circuits to be adaptively turned off. The work introduced in [6] demonstrated that when the system's data rate demand is moderated it leads to a fewer utilization for the antennas which in turn results in a higher EE. In addition, the work reported in [7] found that the number of RF chains should remain equal to the number of active users. This could be achieved through developing a selection system that combines the RF chain with user scheduling. While the work proposed in [11]–[17] assumed that the portion of the BS will be immediately switched into the off mode when the network is under low traffic conditions. The works introduced in [11], [12], [16], [17] proposed a new traffic-aware BS turning off method. The proposed approach attempts to optimize the process of managing the power consumption without taking into account the users' quality of service (QoS) needs.

Moreover, the work proposed in [12] assumed that the given data rate needs from the customers lead to a significant reduction in the total number of turning on BSs [12]. The research work reported in [13] revealed that the idea of switching the BSs to the sleep mode leads to saving up to 33 per cent of energy while maintaining the efficiency of the network. However, we found that most of these previous research works including those relying on the idea of turning off the antennas [18] and turning off the BSs [11]–[17] are designed to work with single-cell systems only. The idea of BS collaborative transmission proposed in [19], is widely regarded as a potential technique for increasing spectrum efficiency, particularly for cell-edge users. Last but not least, the work proposed in [20] tackled the issue of EE by introducing multi-cell cooperative methods to check if such a method can help in improving the EE of these cellular systems. The issue of trade-off between energy and spectral efficiency for the uplink cooperative systems has been examined in the work introduced in [21]. Besides, the work reported in [22] has shown that the idea of cooperative transmission results in lowering the density of the deployed BSs while minimizing the transmission power by searching for the best plan that ensures an efficient energy consumption for the network.

In this regard, it has been found that for the cooperative transmission, the EE of the cooperative transmission will rise by up to 20 per cent. Thus, it has been found that switching off those BSs which are under low load and the idea of employing the BS cooperative transmission to increase the EE in cellular networks is an effective technique to improve the EE [23]–[25]. To minimize the circuit power consumption, a few of the BSs in a cooperative cluster were placed into sleeping mode, and subsequently, its associated users were cooperatively serviced by the remaining active BSs [23]. Turning off the BSs using cooperative transmission resulted in a possible power savings of up to 50%, according to the work reported in [24]. All of these efforts [18]–[24] have been directed at multi-cell cooperative systems in homogeneous networks. This paper introduces a cooperative approach for improving the EE by adaptively turning off certain BSs and dynamic antennas. The idea of turning off some BSs and changing the antenna operating pattern according to traffic load need helps to achieve a balance between meeting the QoS requirements of users and EE. To demonstrate the potential energy savings, we first discover the best solution for switching off some BSs scheme that is based on the real-time channel information. Second, we try to explore a dynamic antennas scheme that is dependent on QoS.

The remainder of the paper is structured as follows. Section 2 introduces and explains both the proposed system model and the power consumption model. Section 3 proposes an improved approach for managing energy efficiency for turning off BSs and a dynamic antennas scheme. The simulation setting and the result findings are reported in section 4. The conclusion has been set out in the final section, section 5.

2. SYSTEM AND POWER CONSUMPTION MODEL

This section explains the proposed technique introduced in this work for combining the LTE and 5G networks. The idea of the proposed solution is inspired by the concept of turning off 5G-BSs and employing several antennas for LTE-BSs, which considers QoS for each user as well as energy savings. The 5G small cells are merged with the current microcell of the LTE macrocell the cellular network architecture model examined in this study, as illustrated in Figure 1. Every seven 5G small cells can be covered by a single microcell of the LTE. In addition, all of the network's cells are linked by a central office-based switching off/on the server.
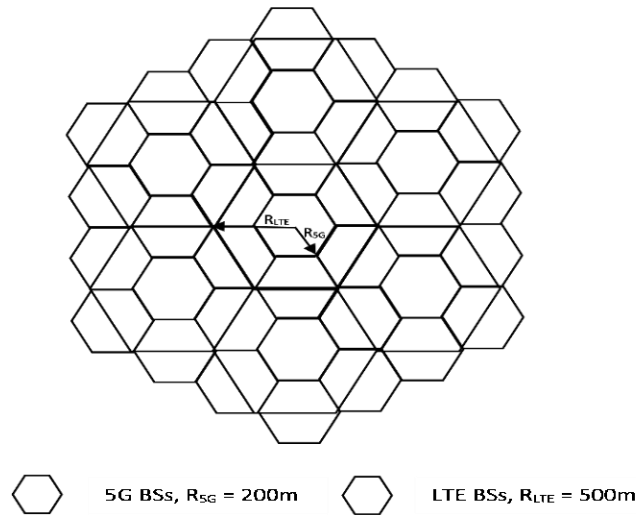

Figure 1. A cellular network's topology

The suggested method is based on a dynamic BS switching off/on and the antennas technique to establish a balance between the network performance and the EE depending on traffic demand circumstances. Figure 2 illustrates a real-world wireless CN traffic profile that has been adopted from the work in [26]. Most often, the daytime traffic profile is greater than the nighttime traffic profile. It has been observed that there is a significant traffic load that varies from 0.4 to 1 during the period from 10 a.m. to 11 p.m. (13 h). In contrast, the network traffic load is low and varies from 0 to 0.4 during the duration from 11 p.m. to 10 a.m. (11 h) as demonstrated in Figure 2.
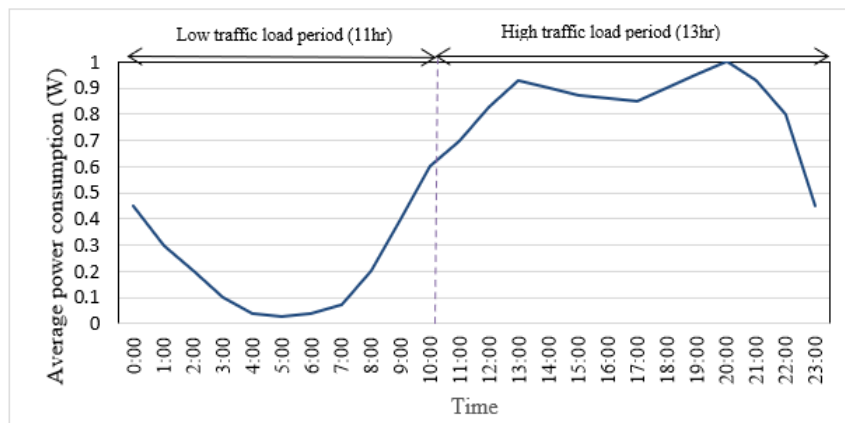

Figure 2. The pattern of downlink traffic load daily

A 5G BS is scheduled to be turned off during the off-peak time, while the remaining active LTE BSs with a restricted number of active antennas will provide coverage for users and sustain the network's

core functions. The flowchart for turning off/on the BS and antennae, on the other hand, is supposed to follow specific criteria. The recommendations should take into account execution, assessment, and energy usage.

3. METHOD

This section presents and discusses the detailed processes in the proposed enhanced energy-efficient management technique for switching various BSs and antennas. The main aim of the proposed approach for managing energy efficiency is to minimize the power usage during the low load time for the BSs in the network. The proposed approach consists of five main stages, which are elaborated in detail below. The process flow and the stages of the proposed approach are depicted in Figure 3. The 5G base station (BS) is responsible to monitor and observe the produced traffic load regularly (once every few minutes) to determine when it is necessary to switch off those 5G base stations (BSs) aiming at saving energy and improving the performance of the network. The idea of the process of monitoring those base stations (BSs) suggests that the decision to switch off the BS depends on a predefined threshold traffic load value ($\lambda \leq 0.4$) that might remain for a specific time. If the current traffic load of the BS is equal to or below this threshold value for a certain amount of time, then the BS will be immediately switched off. The main reason for setting the traffic load benchmark value to be 0.4 is that as we mentioned in the previous section, the traffic load will be reduced to less than or equal to 0.4 [26]. This information is solely determined by each 5G base station (BS).
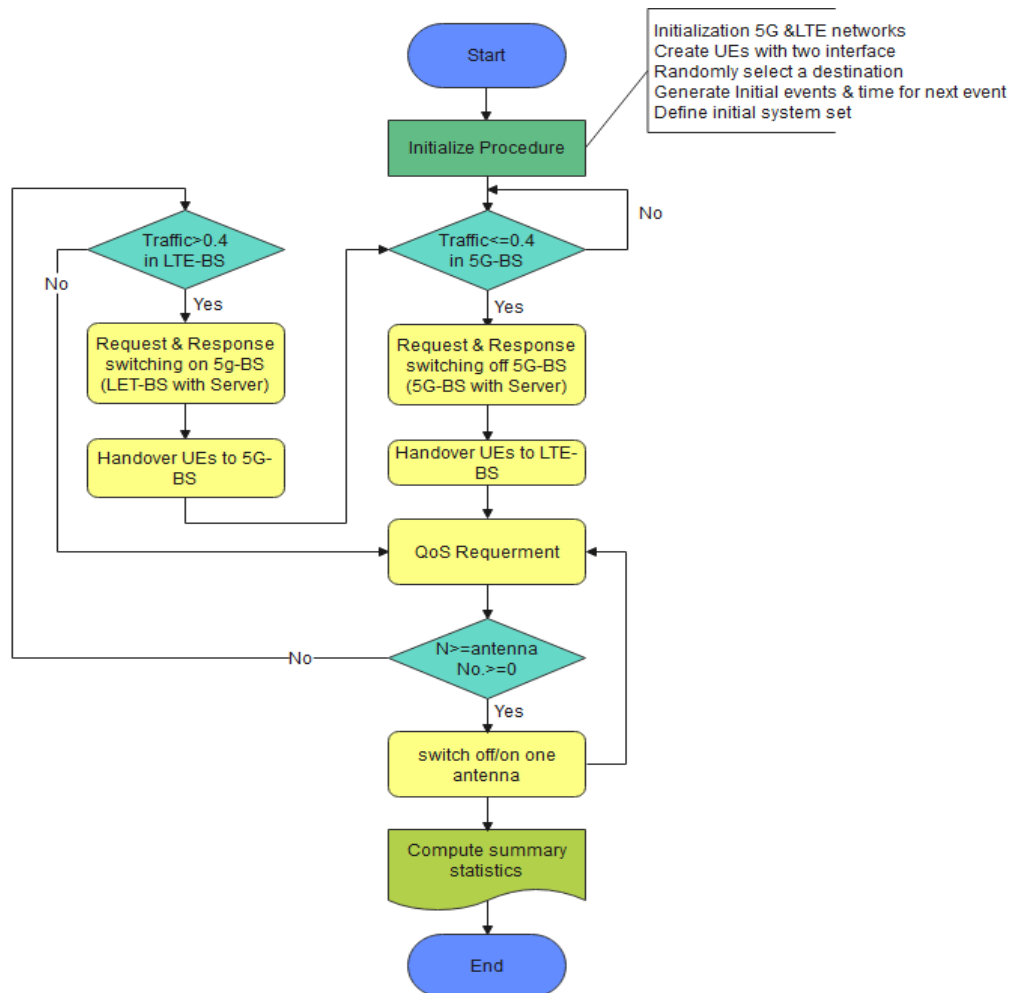

Figure 3. The flowchart of the dynamic antennas algorithm

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−　First, the 5G base stations BSs send a unicast control signal to the switching off/on the module at the central office requesting to turn off all base stations (BSs) of the 5G network. When the switching off/on module sends a response signal requesting to continue with the process of turning off the BS, the 5G BSs begin a progressive drop in transmission power, which eventually results in switching off the BS. In the meantime, the user equipment (UEs) which is responsible for the switched-off 5G BSs are reallocated to active LTE BSs in the designated area. It should be noted that this process determines based on the signal strength of the network. The main distinction is that this process is similar to the present handover technique in which includes handing over a group of UEs rather than a single UE. Group handovers have been the subject of much investigation in recent decades [27]–[31]. Most of the research efforts relevant to the issue of handover focused on commuter support for mass transportation systems such as buses and trains [32]–[35]. A technique to anticipate the group handover a priori may be required that will help to prepare the UEs to hand over from 5G-BS to LTE-BSs. In this scenario, one of the current group handover approaches [33] may be adopted to implement our proposed group handover policy, together with our suggested switching-off algorithm. The main reason for adopting the work in [33] in our work is that the scenario of the handover process to a group of UEs that takes place between two different networks is similar and will be best used in our proposed approach.

−　Second, turned-off 5G BSs wait for the switch/on the server to provide a wake-up control signal. Simultaneously, active LTE BSs can meet customers' QoS needs. The number of antennas could increase or decrease based on the network traffic and each user's quality of service requirements. If the number of antennae is more than the total number of antennas or equal to zero, then, the LTE BSs will determine whether or not to switch/on the 5G BSs when network traffic load exceeds the threshold value (0.4). This process is very beneficial and helps in optimizing the number of active antennas at each LTE-BS based on QoS requirements for the UEs at this stage. To achieve our goal, at each specific time, we will turn off one antenna at the BS to reduce the average power usage while preserving the minimum requirement for QoS.

−　Next, the decision to switch on 5G BSs mainly depends on the LTE BSs signal information. During this process, it is possible to use the 5G BSs switching-on decision if the current load exceeds the given threshold value of the network traffic load (0.4) and this traffic load remains above the threshold for an extended period. The process begins by sending a unicast control signal from the LTE BSs to the switching-off/on module requesting for the 5G BSs to be switched on. The multicast signals are sent to reactivate the offline 5G BSs' control signals once the traffic load has been assessed and the switching-off/on module considers it essential to switch the BS. This, in consequence, leads the 5G BSs to progressively raise their transmission power and, as a result, send a unicast signal to the switching-off/on module, which contains the answer to the switch-on request. It should be noted that the UEs served by LTE BSs are turned over to active 5G BSs using signal strength paths parameters (small cells). The signal strength route of the UE BS is the main determinant of this switching process. Meanwhile, LTE BSs continue to operate to enable the 5G BSs while ensuring coverage and radio services.

−　Last but not least, after completing the process of analyzing the current traffic load, and requesting for the 5G BSs to be turned on. The 5G BSs become operational during this phase and continue to monitor the UE load flow.

4.　RESULTS AND DISCUSSION

In this study, we simulated the proposed technique in this research work and compared it with the most recent relevant techniques introduced by [11], [18]. To facilitate the discussion of the simulation results in this research work, we called the technique proposed in [11] method 1, while the technique proposed in [18] method 2, respectively. Table 1 shows the parameter settings for the simulation that have been utilized in this study, which is taken from [11]. In this work, the NS2 network simulator has been employed to design and implement all techniques consider in this research work. In our experimental study, we assumed that the 5G BSs are turned off during the off-peak traffic load demand, and the number of antennas in LTE BSs is gradually reduced, taking into account the quality of service for each customer. Our technique development and implementation are targeted at lowering energy usage for the network during off-peak times. By varying the values of the parameter, the performances of potential techniques were compared against other

techniques. Based on our proposed approach, this section presents and discusses the performance evaluation of the LTE BSs optimization issue when the 5G BSs are turned off/on. Since the EE is a function of both the data rate and the overall BS power consumption, therefore, this work focuses on the QoS that will be supplied to the UEs.

Figure 4 shows the average power consumption of our proposed scheme compared to method 1 [11] and method 2 [18]. Given the number of active antennas, the power consumption drops first in a low-traffic scenario (energy-saving case), the 5G BSs are turned off, and coverage is ensured by LTE BSs, subsequently, the high-traffic situation, when both LTE and 5G cells are operational and serving network users. However, preference is given to 5G small cells that can offer the lowest data rate at the 5G cell's edge. When the QoS requirement is minimal, a smaller number of active antennas is recommended; otherwise, a larger number of active antennas is preferred. This is due to the fact that circuit power consumption is disproportionately high at low QoS requirements, therefore turning off more antennas can lower overall power consumption for the network. Activating more antennas to meet a high QoS demand might increase power consumption for the network. This demonstrates that the proposed solution outperforms the other two solutions (method 1 and method 2) in terms of network performance. This is because the proposed strategy makes use of dynamic antennas, which are reliant on user QoS.

Table 1. The simulation parameter settings

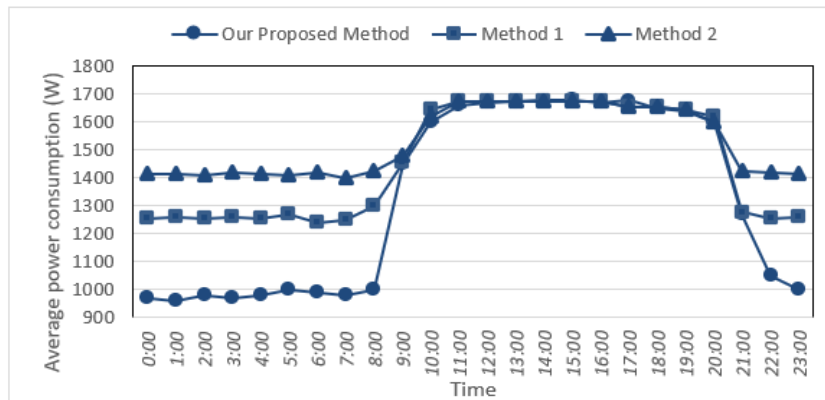| Parameters	Variable Used
Network Topology	
5G cell coverage	Disk with radius= 200 meters
LTE cell coverage	Disk with radius= 500 meters
Frequency	2.6 GHz
Bandwidth	1.4-20 MHz
Transmission power	40W
Antennas height	20m
User Equipment	
Thermal noise density	174dBm/Hz
Noise figure	9dB
Implementation margin	3dB

Figure 4. Average power consumption vs time

In Figure 5, we use simulations to assess the energy efficiency accomplished of an LTE-BSs utilizing dynamic antenna switching during low traffic (11 p.m. to 10 a.m.) for our proposed technique compared to certain BSs and antennas active in method 1 [11]. The number of bits transferred per energy unit is used to compute the energy efficiency measure. Because both the numerator (the number of supplied bits) and the denominator (network energy consumption) are generally changeable, the energy efficiency metric is acceptable for our network. As a result, for networks with low traffic loads, the efficiency metric is more practical. It is obvious that our proposed approach leads to a significant saving in the energy consumption for the 5G network, particularly in systems with a limited number of antennas at each base station, where the number of effective antennas is regulated based on the quality of service required for each user. When the necessary data rate is 3 bps/Hz, the optimum dynamic switching technique has an EE gain of nearly 64% when compared to method 1 and 87% when compared to method 2 [18].
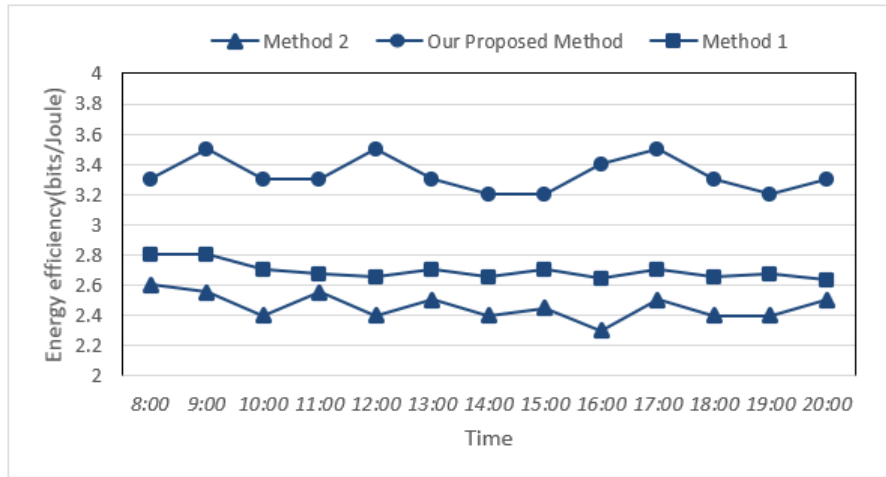
Figure 5. Energy efficiency vs time

Finally, the proposed technique is briefly addressed in terms of the energy savings it achieves. The simulated configuration consisted of seven 5G base stations, each of which covered a smaller area than the LTE base station (as illustrated in Figure 1). During peak time (10 a.m. to 11 p.m.), the 5G-BSs are only active for 13 hours (10 a.m. to 11 p.m.), and they are in sleep mode the rest of the time (as shown in Figure 2). During high-traffic periods, LTE-BSs guarantee 5G-BS support, but during low-traffic periods, LTE-BSs have two functions: data transmission and ensuring QoS requirements for each user. The Energy (E) of Methods is calculated as [36]:

$$E_{method}^{day} = \sum(N_{BS} * P_{Cos}) * day\ active\ time\ (hours)$$

Where:
N_{BS} represents the number of active base stations for LTE and 5G networks.
P_{Cos} indicates the power consumption for one base station in LTE or 5G networks. The formula to calculate the P_{Cos} has been taken from the work in [34].
We simplify the above equation to fit our proposed work as:

$$E_{method}^{day} = \left[\left(\alpha_{LTE\_BS} * P_{Cos}\right) + \left(\beta_{5G\_BS} * P_{Cos}\right)\right] * h$$

Where:
α indicates the number of active base stations in the LTE network.
β denotes the number of the active base station in the G5 network.
h represents the total number of hours in which the stations in both LTE and 5G networks are on in a day.
We present the calculations of the energy consumption for methods 1, method 2 and our proposed method. For simplicity and without loss of generality, we assumed that the total number of active base stations in the LTE network (α) equals 7, while the total number of active base stations in the 5G network (β) equals 37. In addition, we assumed that the number of hours (h) in which LTE base stations are active is equal to 13 hours, while the total number of hours (h) in which 5G base stations are active is equal to 11. Finally, the power consumption (P_{Cos}) for method 1, method 2 and our proposed method has been calculated using the formula given in [36].

$$E_{method\ 1}^{day} = [(7 * 571.8) + (37 * 45.1)] * 13 + [(7 * 571.8) + (37 * 0.9)] * 11 = 118.03\ kWh$$

$$E_{method\ 2}^{day} = [(7 * 571.8) + (37 * 45.1)] * 13 + [(7 * 451.8) + (37 * 0.9)] * 11 = 108.01\ kWh$$

$$E_{our\ proposed}^{day} = \underbrace{[(7 * 571.8)}_{LTE\text{-}BSs_{(on)}} + \underbrace{(37 * 45.1)] * 13}_{5G\text{-}BSs_{(on)}} + \underbrace{[(7 * 205.3)}_{LTE\text{-}BSs_{(dynamic)}} + \underbrace{(37 * 0.9)] * 11}_{5G\text{-}BSs_{(off)}} = 95.97\ kWh$$

$$\underbrace{}_{High\ traffic} \qquad \underbrace{}_{Low\ traffic}$$

From the above calculation, it is obvious that our proposed solution manages to reduce the energy consumption and save up to 12.04 kWh per day compared to method 2 [18] which produced 108.01 kWh and save up to 22.06 kWh in comparison to method 1 [11] that generate 118.03 kWh. This improvement in energy consumption satisfies the demands of mobile customers for high-speed data during peak hours. Based on the network configuration illustrated in Figure 1, Figure 6 illustrates the maximum percentage of energy saved vs time. However, the amount of energy saved relies on the number of active antennas for LTE-BSs that will be turned off in this way. The energy savings will be significant if a large number of antennas are switched off.
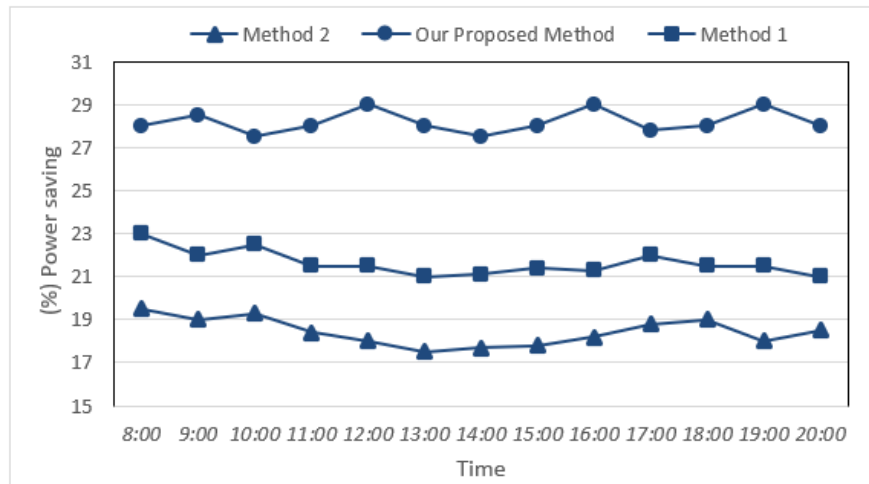
Figure 6. Maximum percentage of energy saved vs time

5.   CONCLUSION

The present dense BS deployment, which is driving the narrow coverage area idea, has produced unexpected traffic patterns for each BS, bolstering the suggested dynamic antennas switching-on/off algorithm. By monitoring the network's traffic load and QoS and choosing whether to turn off or on some LTE-BS antennae, the suggested techniques save energy. This research attempted to examine the potential of establishing a balance between network performance and energy savings in dual-radio access cellular networks by 5G-BSs switching off/on and some LTE-BSs antennas, which reflected the current traffic load condition while ensuring a high level of service for all users. The simulation results showed that the proposed approach outperforms the previous recent approaches in saving up to 22.06 kW per day in energy consumption. However, the amount of energy saved by our proposed approach is dependent on the number of LTE BS antennas that are turned off. Last but not least, we are planning to further investigate the issue of switching off/on of 5G-BSs under an offloading technique as this issue is considered as one of the most crucial concerns in 5G networks.

ACKNOWLEDGEMENTS

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