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Optimize Energy Efficiency Through Base Station Switching and Resource Allocation For 5g Heterogeneous Networks

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Abstract: Energy and spectrum are the crucial factors on which future heterogeneous networks maintain green and sustainable development depends. Optimization of spectrum and power is the need of the day. The proposed algorithm uses Base Station (BS) switching model for the power optimization in which BS is made to sleep/ awake based on the user density and precursory observed data. With this dynamic control of the power of BS, a considerable power saving is observed. Spectrum optimization is attained using spectrum slicing, in which, initially, the traffic modeling is done considering user density, demand, and other parameters. Then the data assembled is deeply analyzed, and then Hidden Markov Model is used to allocate the spectrum based on the initial processing. This technique helps in the effective distribution of spectrum, and the spectrum can be appropriately utilized among the users belonging to different density groups having varied applications. The paper aims to increase spectral efficiency and power optimization with improvement in the Quality of Service (QoS) in addition to the user's quality of Experience (QoE).

Keywords: *Base station (BS) switching, Energy Efficiency, Resource Allocation, Spectrum Slicing, Traffic Modelling 5G*

1. Introduction

Mobile traffic has been growing gradually owing to the wide rise in the number of users and different uses. Since the conventional network is unable to fulfill that ever-increasing demand, 5G will serve as a boon for it. As the technology is growing, the demand for it also continues to grow, and traffic, interference, and low data rates are also observed in the 5G networks. To encounter the Quality of service (QoS) and Quality of Experience (QoE) necessities of the users, it is necessary that some technologies must be incorporated into 5G for its effective service; to meet the demands of the end user in a polished way. One approach to tackle these challenges could be to use a heterogeneous network concept where traditional Macro Base Stations (MBS) are deployed to provide the main coverage of the network to the users for the coverage of the large area, and low-powered small base stations are present for the coverage of smaller areas. Different tier systems will be present here, containing small and large cells, so it will provide increased bandwidth, reduced latencies and higher data rates, which will overall increase the QoE and QoS experience of the user.

Energy efficiency is one of the major concerns as far as 5G wireless networks are concerned. High energy requirements increase operators' costs and contribute to the emission of harmful greenhouse gas. In addition to energy efficiency, there is a necessity to upsurge the spectrum efficiency of the network. Spectrum is very crucial and partial and hence utilizing it effectively is of utmost importance. Due to increased traffic, the spectrum gets overloaded, and interference occurs. Call drops, low latencies, and low signal-to-noise ratio are obtained will overall lead to deteriorated QoS and QoE.

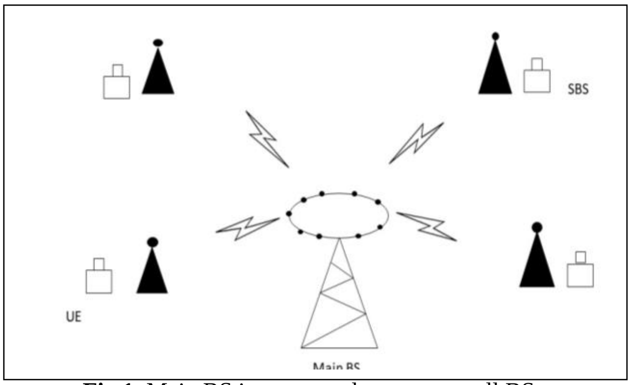

Fig 1. Main BS is connected to many small BS.

Figure 1 shows that the main base station is connected to many small base stations for better coverage and low interference, but the energy consumed by all these base stations is huge. The network must be planned in such a manner that it must be competent to meet the user's demands and maintain the quality of service and experience by consuming less energy and spectrum. Spectrum slicing is one of the prominent technology which helps in the efficient utilization of spectrum amongst the different user density areas and reduces the interference rate in the high-density areas by providing a major portion of the spectrum to it.

The deployment of many small base stations drastically increases the coverage, lessens the interference, and increases the signal-to-noise ratio, but this, in turn, raises total energy consumption. The power due to this is significantly increased, which not only increases the overall cost but is also harmful to the environment

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causing Greenhouse gas emissions. Thus, energy saving is one of the key concept which is under research. The base station switching (also termed BS sleep control) is a unique way to diminish total energy consumption. Establishing green communication which does not have a potentially harmful impact on the environment is a big challenge for sustainable development. When base stations are not in use, they can be switched off, leading to enormous energy savings.

Hence spectrum Optimisation and base station switching are prominent areas of concern as far as a 5G heterogeneous network is concerned. So, we have developed an algorithm for the optimization of spectrum using spectrum slicing and a strategy for base station switching. The remaining paper is organized as follows: part 2 of this paper shows the extensive research which was done in the past in the concerned area, part 3 provides the algorithm for the strategy to be followed, and part 4 gives the results followed by the conclusion.

2. Background

A model of BS sleep is proposed in [1], where the power consumption has a different set of values for different kinds of base stations.[6] proposed BS ON/OFF control schemes for reducing total energy consumption in heterogonous networks.[7]demonstrated a centralized awake/sleep for the BS for waking up and sleep of femtocells. According to the location, the wake-up message is sent to the femtocell when the traffic increases. Energy can be optimally used by using adaptive modulation, multi-antenna, and spatial multiplexing as specified in [8]. Several techniques to reduce carbon footprints are mentioned in [2], leading to green communication. Reinforcement learning is used to consider power efficiency and optimize mobile femtocells' performance. [14]It provides better network performance and interference management. An energy-efficient radio resource allocation algorithm (EERRAA) was illustrated in [16] for increased throughput, less intrusion, and enhanced network efficiency.

Spectral efficiency, system throughput, and increasing traffic can be maintained by D2D communication, which is mentioned in [3]. The author described D2D technology and its need to meet the ever-increasing need for spectrum and interference management in 5G networks. Spectrum sharing and many techniques for better spectrum utilization are mentioned in [4] because spectrum and energy are the key factors in any communication network. Cognitive sharing of resources [9] is an efficient spectrum utilization technique in a 5G network. To increase the quality of service, massive MIMO is used in the heterogonous network[11]. Spectrum and energy-efficient massive MIMO are used in cognitive radio networks.[13]

In the algorithm which we have developed, we have tried to fill the research gaps which were deeply studied and observed during the extensive literature survey mentioned above. The spectrum utilization, SINR, and throughput are increased, and with the BS switching ON/OFF mechanism, energy saving is achieved. Our design illustrates the key factors of a 5G heterogonous network, i.e., spectrum optimization and reduced energy consumption.

3. Methodology

3.1 Base Station Switching

The base station power model demonstrated here controls the consumption of power and thus makes the overall system much more efficient. This base station is operated on various modes, which are as follows:

3.1.1 **Active mode**: This is the mode of normal operation of the base station in which it is capable to transmit and receive the signals devoid of additional activation or deactivation. In this there is no delay and initially the base station is in active mode. All the normal operations will be performed.

3.1.2 **Sleep mode**: This is the energy saving mode of the BS. The BS activates or deactivates according to the training provided. While the BS is in sleep mode the synchronization signals are send time to time so maintain coordination with the main BS.

3.1.3 **Deep sleep mode**: While the base station is in sleep mode for longer duration as fed in the database then it enters automatically in the deep sleep mode and complete energy saving mode in this BS can't transmit or receive anything

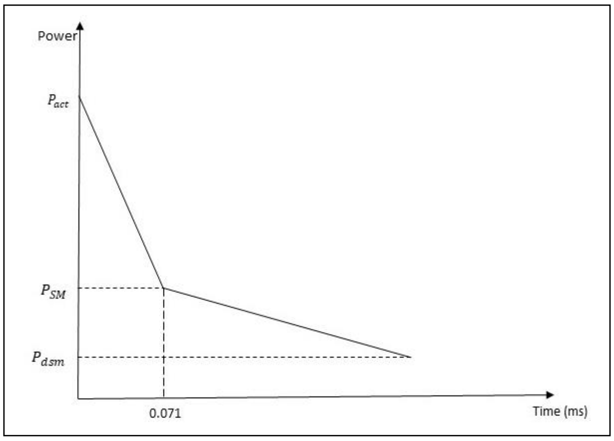

Fig. 2. Power Consumption with time in various sleep modes

Figure 2 shows the reduction in s consumption as the BS enters sleep mode or deep sleep mode from active mode. During the waking up of BS from sleep mode, the complete process is reversed.

The selection of the constraints at which time a BS station should enter a sleep mode depends upon the user density, number of active users, coverage, and capacity of the small cell. The macro cells are hexagonally arranged in an outmoded cellular system to offer full umbrella coverage. But due to huge traffic and data rates and an increase in user applicability small cell BS need to be deployed. These small cell BS consume huge power, so it's a good idea to turn them OFF when not in use or when the traffic is less. The traffic pattern daily is learned for a particular area, and based on that, the BS is made to learn that pattern of switching ON and OFF during that particular time frame.

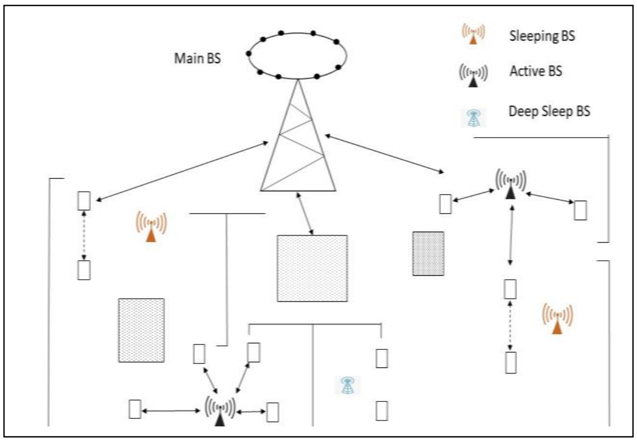

Fig. 3. An Illustration of BS switching

The diagram above depicts an example of base station switching during traffic. SBS is an active mode, but when traffic is not there, the learning is fed into it so that it gets into sleep mode, and when the sleep mode continues, the SBS itself goes into deep sleep mode. The main base station is connected to 3 to 4 small base stations in this diagram, which are again connected to the user equipment.

The Heterogeneous 5G network consists of massive numbers of base stations, and they consume enormous energy in the network. So, in the model described here, the BS is active only when used and made to sleep when not in use. Deep sleep mode is enabled during the phase of complete inactivity (sleep mode for a significant period). This can help in the reduction of energy consumption. However, many constraints must be kept in mind while making a BS sleep, as it dramatically affects the coverage and connectivity of the end user. Firstly, the range of the end user must be taken into consideration. Secondly, the capacity of the small cell BS and then the data rates and the quality of service must not be compromised. Assuming that there are s small cells and m number of users. Then, the information of status awake/sleep mode for s small cells is shown in the equation:

XB = {x1………. xi……….. xs}

Where xi represents sleep or awake mode. To describe the connectivity of BS and end users, we have designed a matrix Y in which each row represents the number of base stations, and the column represents the number of end users.

$$Y = \begin{pmatrix} y_{1,1} & \dots & y_{1,k} & \dots & y_{1,m} \\ . & \dots & . & \dots & . \\ y_{z,1} & \dots & y_{z,k} & \dots & y_{1,m} \\ . & \dots & . & \dots & . \\ y_{s,1} & \dots & y_{s,k} & \dots & y_{s,m} \end{pmatrix}$$

The main aim is to keep the minimum number of base stations in the awake mode if the base station is in sleep mode for more than the threshold time, letting them enter into deep sleep mode, maintaining the mentioned criteria so that energy efficiency can be maintained.

Objective: $\min \sum_{i=1}^{i=s} \mathrm{E.\,xi}$

Firstly the base station needs to sort based on geographical information, and then BS is selected for communication purposes. Then, the reduction in awake BS is made by not compromising the coverage. Then the BS, which is not in use for a long time, is sent into a deep sleep state.

3.2 Spectrum Slicing System Model

Spectrum slicing is an effectual frequency or spectrum distribution technique that provides great QoS and QoE o the user by providing less interference and lower latencies. Therefore, optimization of spectrum usage can be efficiently achieved by spectrum slicing. In the model mentioned below, two steps are used for network slicing. Firstly, the traffic pattern is analyzed, and the database is fed accordingly. Secondly, Hidden Markov Model (HMM) is used to slice the spectrum. There are several factors on which spectrum slicing using HMM depends, including the number of users, frequency of the users, demands of the data rate of the users, and signal-to-interference noise ratio. So, modeling of traffic and its analysis is required for the purpose of slicing the spectrum efficiently using the Markov rule.

Let the number of users in the presented cellular architecture be U such that U= {1,2.3……u}. Let the set of user density in the High-Density Area be $H_{n'} = \{1,2,3, \dots \dots \dots \dots . . H_n\}$

Let the set of user density in Medium Density Area be

$K_{n'} = \{1,2,3, \dots \dots \dots \dots . . K_n\}$

Let the set of user density in the Low-Density Area be

$P_{n'} = \{1,2,3, \dots \dots \dots \dots . . P_n\}$

Spectrum slicing helps in increasing SINR and hence decreasing the total interference and shown as

$SIN(i) = P_{BS}(i)g(i)/\Omega_n + I(n)$

Where P_{BS} is the transmission power of the base station, $I(n)$ is the interference amongst present users, Ω_n is the receiver noise power, and $g(i)$ is the channel gain.

Let x be the total number of users and R be the total number. So, the throughput and energy efficiency will be given as

$$T_m = \sum\nolimits_{x \in R} T_i(x) / \sum x$$

Energy efficiency is defined as

$E(i) = T_s/P_{BS}$

Where T_s is channel throughput and P_{BS} is the total transmitted power and

Spectral Efficiency

SE (j) = Number of users/ (Bandwidth)

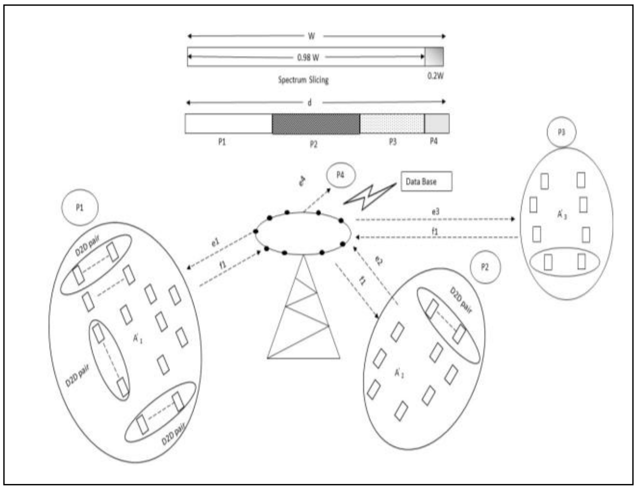

Fig. 4. An illustration of the system model for Spectrum Slicing

The symbols used the above figure are provided in the table below:

P_1	Spectrum provided to a high-density area
P_2	Spectrum provided to medium density area
P_3	Spectrum provided to low-density area
P_4	Spectrum reserved for emergency uses
A'_1	High-density area
A'_2	Medium density area
A'_3	Low-density area
f_1	Demand/ requirement of the area from BS
e_1	Channel Capacity of HDA
e_2	Channel Capacity of MDA
e_3	Channel Capacity of LDA
e_4	Channel Capacity of the reserved area

The complete spectrum available to us is considered as w, and 98% of it is used for transmission, and 2% is kept for urgent uses as illustrated in the figure. Using the spectrum slicing technique, the spectrum is divided or sliced as P1, P2, P3, and P4, respectively. Major portions of the spectrum are provided to high-density areas, i.e., where the user density is more and is named as P1, some less amount of spectrum is provided to medium density area where the user density is average and is called P2 and where the user density is very low that area is called as P3 and P4 is the spectrum which is reserved for emergency uses. The main station is connected to all the regions and provides the required signals needed for the operation.

3.3 Issuance of Spectrum using HMM

The traffic analysis spectrum is sliced first, based on the Hidden Markov Model (HMM). Consider $A_1, A_2, A_3, A_4 \dots\dots\dots A_n$ are distinct states, and here we assume n=4.
Let x be the time interval; so the conditional probability will be defined as

$$P(Z_x \mid Z_{X-1}, Z_{X-2} \dots\dots\dots . . Z_1)$$

For the first order HMM, this equation can be simplified as

$$P(Z_x | Z_{X-1}, Z_{X-2} \dots\dots\dots . . Z_1) = P(Z_X \mid \quad Z_{X-1})$$

At a particular instant of time Y_x, by using Bayer's Rule, the conditional probability can be defined as

$$P(Z_x | Y_X) = P(Z_X | \; Y_X) P(Z_X) / \; P(Y_X)$$

For HMM, here, four stages are considered Base station, High-Density Area (HDA), Medium Density Area (MDA), and Low-Density Area (LDA), as depicted in the figure. 98% of the spectrum is sliced, and 2% of it remains unused for emergency uses.

As per the traffic analysis, the users will be classified whether they belong to HDA, MDA, or LDA, and the spectrum is sliced based on user density, traffic, and low interference.

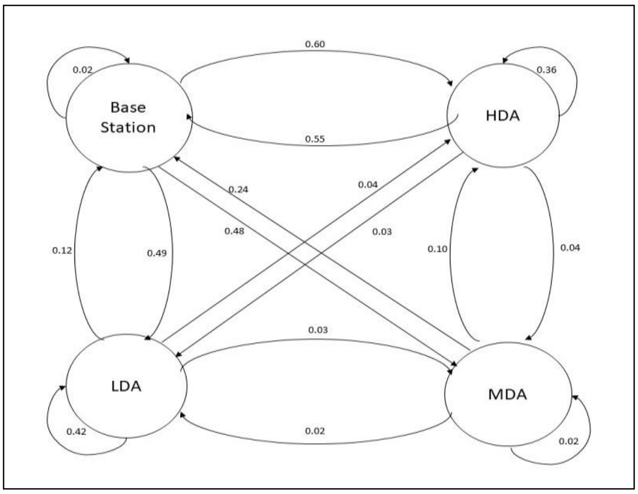

Fig. 5. State Diagram for Spectrum Slicing.

The probabilities of transition are provided in the table, where it can be easily observed that the majority portion of the spectrum is provided to the area with a High Density of users. This technique will lead to the effectual utilization of the spectrum, and the needs of users belonging to different density areas will be fulfilled.

Table 1: Transition Probabilities

Demand	*Response*			
	Base Station	HDA	MDA	LDA
Base Station	0.22	0.600	0.24	0.12
HAD	0.55	0.36	0.04	0.03
MDA	0.48	0.10	0.28	0.02
LDA	0.49	0.04	0.03	0.42

3.4 Representation of Algorithm using flowchart

This section demonstrates the flowchart for the calculation of user density for traffic analysis, and based on that analysis Hidden Markov rule will be applied for the spectrum slicing

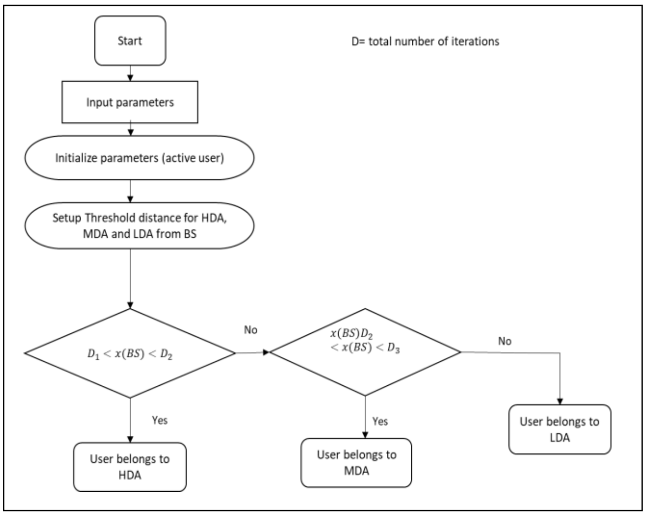

Fig. 6. Flowchart for the calculation of user density

In figure 6, firstly, the parameters such as the power of the base station, number of users, channel, and bandwidth are taken as input. Then the parameters are initialized. Then the remoteness of the active users from the base station is calculated using distance formula based on that users are classified to which user density area they belong. A threshold distance is already calculated and is fed for the approximation. If the distance iteration lies in a particular range, it belongs to a specific field, which is mentioned in the flowchart presented above. Here D represents the total number of iterations. So with the help of this, users can be identified, and traffic analysis will be done, which will serve as input or step 1 for the spectrum slicing to take place.

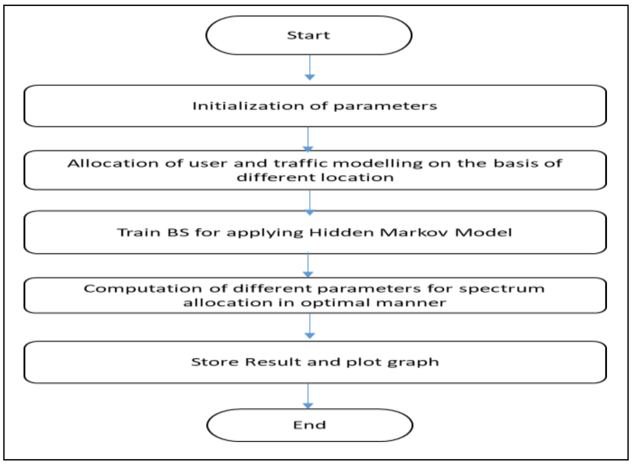

Fig. 7. Flowchart for the Proposed Algorithm of Spectrum Slicing

The above flowchart in figure 7 represents the complete algorithm for the spectrum slicing. First, the input parameters are initialized, and then traffic analysis is done, as illustrated in the previous flowchart.

After traffic analysis is done, the BS is trained using Hidden Markov Rule. With the help of this spectrum, slicing takes place, and then the users are allocated to different sliced spectrums respectively. Then finally, computation of throughput and spectral efficiency is done. Lastly, graphs are plotted to map the result.

4. Results and Discussion

This section will contain all the results and comparisons obtained after the simulation. The scenario will tell about the coordination of BS with different users when slicing is done. The simulations for the network model are done for 5G on MATLAB.

The table below indicates various simulation parameters. The main aim is to optimize the power and efficient use of the spectrum. The allocation of spectrum by using HMM and multiple parameters.

Bandwidth per user = Total bandwidth/Total number of users

Table 2: Parameters for Simulation

S.No	Parameters	Values
1	Macro-cell radius	0.5 km
2	No. of users in the cell	100
3	Minimal distance of the user from BS	0.038 km
4	Path loss exponent	2
5	Carrier frequency	1.8 GHz.
6	Path loss distance 'd' from BS	14.61+37.5logd dB
7	Path loss for MDA at distance d (km)	180.4853 +37.64log10(d) dB
8	Path loss for HDA at distance d (km)	196.5753+38.074log10(d) dB
9	Path loss for LDA at distance d (km)	176.8868+37.68log10(d) dB
10	SNR threshold	2.8 dB
11	Bandwidth	22 MHz
12	The transmission power of BS, PBS	44dBm
13	Receiver noise power	-105dBm

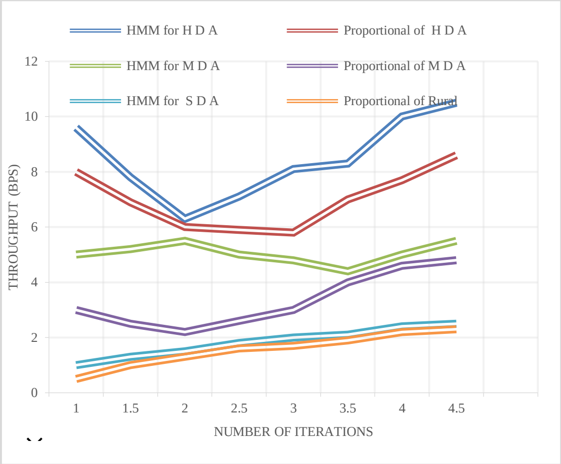

Fig. 8. Throughput Vs. Number of Iteration with spectrum slicing

The allocation of spectrum by using HMM greatly helps in the intensification in throughput and spectral efficiency. Considering the figure it can be easily perceived that the throughput of the system is high for HDA and low for LDA. The spectrum is sliced in such a way that users get the maximum benefit for their required applications. Furthermore, there is an increase in signal-to-interference noise ratio using this approach. Hence, it can be verified that the spectrum slicing approach greatly increased the spectral efficiency, throughput, and SINR.
The comparison of throughput is shown in figure 8 using the proportional algorithm and HMM, in which a rise in the value of SINR is observed owing to spectrum slicing, which in turn upsurges the value of throughput. As High-density area has extreme demand by the users and hence the throughput for HDA is also more.

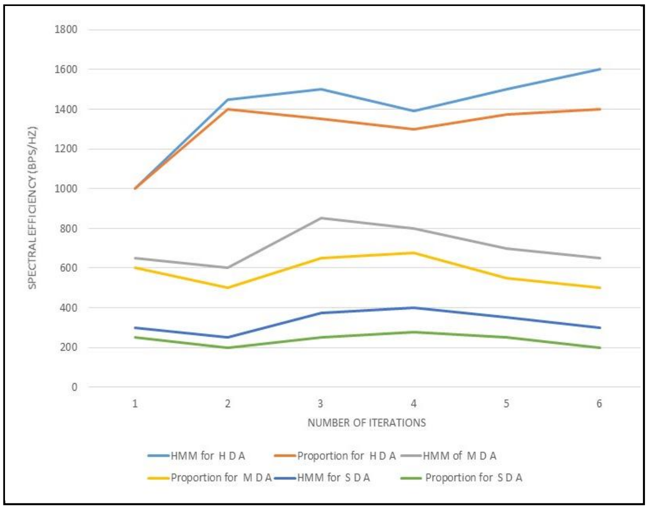

Fig.9. Spectral Efficiency Vs. Number of Iteration with spectrum slicing

The comparison of the proportional algorithm and HMM of the system has been shown in figure 9 for the spectral efficiency of different users. Initially, the value decreases in HDA due to the enormous demand of the user demanding high bandwidth. Subsequently, there is a sudden rise in spectral efficiency.

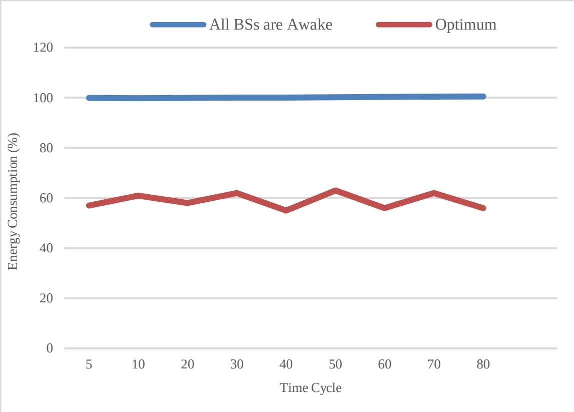

Fig. 10 (a). Energy Efficiency for Uniform Distribution

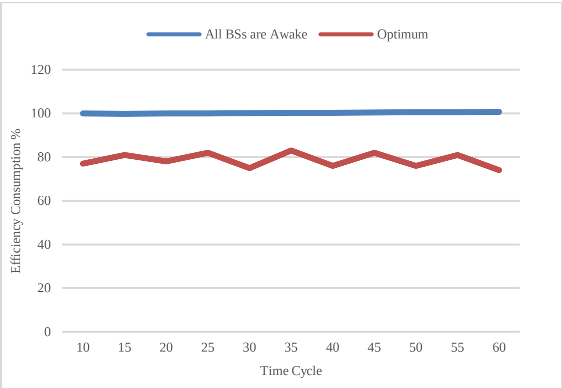

Fig. 10 (b). Energy Efficiency for Non Uniform Distribution

Figure 10 shows the reduction in energy consumption when the BS is switched off as compared to when the BS is fully awake. The improvement in the spectrum efficiency is obtained by using this approach. When the throughput is increased, spectrum efficiency also increases. The spectral efficiency is more in the case of HDA as the throughput is also maximum for this case. In a nutshell, the wastage of spectrum is minimized using this technique. Consequently, it can be perceived that with the usage of the spectrum slicing method, the optimization of energy as well as spectrum takes place.

5. Conclusion

The algorithm proposed by us solves the optimization problem of spectrum in addition to being energy efficient. It thus provides a tradeoff between the two crucial key elements of a 5G heterogeneous network. In the paper, the issues of power and spectrum optimization are addressed. Power optimization is done through BS switching (sleep/awake mode), in which the BS acts in three modes: active, sleep and deep sleep mode. It is made to switch in such a way that power optimization is achieved while addressing the coverage and requirements of the users.

Spectral efficiency is achieved with the assistance of spectrum slicing. A two-step model is used here in which, initially, traffic modeling is completed on the centering of user density for the analysis of the traffic pattern, and then based on data gathered in the database Hidden Markov Model is used for spectrum slicing. The evaluation of the efficacy of our proposed work outcome is carried out, and the graph is mapped to illustrate its potency. The algorithm thus optimizes the power and spectral efficiency, leading toward green and sustainable development.

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