ISSN No:-2456-2165

Towards Power Conservation and Efficiency in Cellular Communication using Triplet Mode Technique

Odo Ebere Clara[1]
[1]Department Of Electrical/ Electronic Engineering, Federal Polytechnic Ohaodo Enugu State, Nigeria

Chijindu Vincent Chukwudi[2]
[2]Department Of Electronic & Computer Engineering, University Of Nigeria Nsukka, Enugu Nigeria

Eneh Joy Nnenna[3]
[3]Department Of Electronic & Computer Engineering, University Of Nigeria Nsukka, Enugu Nigeria

Eneh Afam Samuel[4]
[4]Department Of Biomedical Engineering, Enugu State University Of Science and Technology, Enugu Nigeria

Ezukwoke Nnabuike[5]
[5]Department Of Electronic & Computer Engineering, University Of Nigeria Nsukka, Enugu Nigeria

Ozue Thankgod Izuchukwu[6]
[6]Department of Electronic & Computer Engineering, University Of Nigeria Nsukka, Enugu Nigeria

Abstract:- This research presented energy saving efficiency in a 4G heterogeneous network using Power saving algorithm. This was done after series of literature review which pointed out that various HetNet's suffer from delay time, poor throughput performance, packet loss due to poor transmission efficiency, which also results to high cost of service. These problems were rectified in this research via the development of a Power saving algorithm which allows the user equipment to transmit or receive data using the triplet mode techniques. The algorithm was implemented using MATLAB script and tested with data obtained from Obioma Base Transmitted station(BTs). The result showed that the cell with the best signal strength was used to transmit or receive carrier signal and the energy consumed per hour averagely is 155.6W compared to the characterized with 174W power. The percentage improvement in energy conservation is 10.5%. The energy efficiency of the cell is determined using the model in triplet mode and the result is 54%.

***Keyword*:-** *Power Saving Algorithm, Cellular Communication, 4G Network.*

I. INTRODUCTION

Rapid increasing energy utilization is one of the vital issues related to the problem of global warming and reducing the energy consumption of mobile communication networks is an interesting area of research, that has gained significant attentions since it takes a major part of the total energy consumption of information and communication technology (ICT) Wu et. al., (2015). Since greater traffic is anticipated on upcoming 5G networks in ten years, the impact of the mobile communication network's energy consumption would be more severe according to Fehske et. al., (2011). Hassan et. al., (2011) opined that the base station (BS) is the primary energy-consuming component of mobile communication networks, and that the BS's energy use is influenced by the traffic load, which fluctuates based on the location. There has been a lot of effort done on BS energy savings to help lower the energy usage of mobile communication networks. Turning off BS components as much as feasible while they are not in use is the major focus of their work to decrease energy usage. For instance, the electricity to the majority of the BS's components may be turned off when they are not in use to put the system into sleep mode.

Effective methods to lower or decrease energy usage in 5G network BTs are desperately needed. Although the energy consumption of 5G cellular networks can be decreased by lowering the energy consumption of Base Transceiver Station (BTS) sites, as well as by minimizing the number of BTS sites or by developing effective algorithms with separated control and data planes, the majority of research into the energy efficiency of 4G cellular networks still focuses on the transmission power optimization of Base Stations. The previous research never took into account techniques with separate control and data planes, where the state of a BS is determined based on the number of UEs that request high rate data traffic as well as the number of UEs that are present within the overlapped areas frequently covered by the considered BS and the neighboring BSs. If this technique is used in real time, it will guarantee quality of service and efficient system throughput. They have been numerous works on theenergy saving of a BS in both homogeneous and heterogeneous networks; most of the works have not considered independent operation of data and control plan. Also, works regarding the energy efficiency of a BS in 4G networks with separated control and data planes have focused on the optimization modeling and performance analysis of such separated network architecture.

II. LITERATURE REVIEW

According to Sharma GHTY (2013), the cellular wireless generations (G) refer to a change in the fundamental nature of the service, non-backwards compatible transmission technology and new frequency bands. This is backed up by Ch'avez-Santiago et. al., (2015), who describe the evolution from 1G to 4G as mainly characterized by a shift in the multiple access method, and improved modulation and coding schemes. Multiple access methods, or channel access methods, are methods that handle how several terminals can transmit over the same transmission medium. They are based on methods for multiplexing, i.e. techniques that combine multiple signals into one signal, which is then transmitted over a shared medium. Hossain et. al., (2012) emphasized that the cellular generations have traditionally differed from each other in terms of radio access, data rates, bandwidth and switching scheme. Mogensen et. al., (2017) proposed LTE capacity compared to the shannon bound, System analysis and review of literatures was done. The work compared the LTE layer with the Shannon bound, they used MATLAB/ Simulink to perform the simulation. The Shannon bound model was not characterized before comparison, and hence the result is not justified. Jie Gong et. al., (2015) proposed Cell zooming for cost-efficient green cellular networks, no specific technique was adopted in their work.

The research work focus more on the economic aspect of cellular network. The researcher never presented any technique for his work. Peng et. al., (2013) proposed Self-Configuration and Self-Optimization in LTE-Advanced Heterogeneous Networks, they used Generic algorithm. The work employs a generic tool for the optimization performance of the LTE network. They use MATLAB/ Simulink, communication toolbox. Generic algorithm improves the efficiency of the LTE layer network. Jiyong et. al., (2014) proposed Optimized time domain resource partitioning for enhanced inter-cellinterference coordination in heterogeneous networks. Time domain multiplexing technique. The work optimized the partitioning and cell interference minimization of a heterogeneous network. Opt system, communication toolbox. The work was not characterized and hence the result not justified.

Micallef et. al., (2010) presented Pico Cell Range Expansion toward LTE-Advanced Wireless Heterogeneous Networks. The work reviewed various epistemologies on LTE network, MATLAB/ Simulink. The implementation cost is very expensive. Feng et. al., (2016) proposed Energy Demand Analysis of Telecom Towers of Nepal with Strategic Scenario Development and Potential Energy cum Cost Saving with Renewable Energy Technology Options. System analysis and review of literature. The work analysis the telecom towers with strategic development plans. Communication toolbox, software defined radio, MATLAB, This work serves as a guide for the author for the development of the new system.

III. MATERIALS AND METHODS

The antenna, serving gateway, mobility management entity. All this equipment's are already discussed in the literature review, while the SMW200A vector signal was used to measure the amount of energy consumed in the network during the characterization process and The methodology used to achieve this it is mathematical model, Power saving algorithm and universal modeling diagram. The system was implemented using high programming language and tested using simulation.

➢ *Method of Data Collection*

The data collected was done from the eNodeB device of the base Pico station. This device was logged in using the SMW200A vector signal software to gain access to the user equipment data log and collected data of key performance indicators for transmission energy efficiency which is the power consumed per various times in hour of user activities. The result is presented in the table below.

Table 1 Characterized Data

Time (hr)	**Power (W/h)**
01:00	148
02:00	148
03:00	135
04:00	132
05:00	146
06:00	157
07:00	166
08:00	178
09:00	179
10:00	182
11:00	183
12:00	188
13:00	193
14:00	205
15:00	212
16:00	216
17:00	215
18:00	204
19:00	196
20:00	185
21:00	172
22:00	156
23:00	150
24:00	140
Total	4186W/day

The data in table 1 presented the power consumption performance of the pico cell station within 24 hours. This data was analyzed using excel software and the result is presented below;

ISSN No:-2456-2165

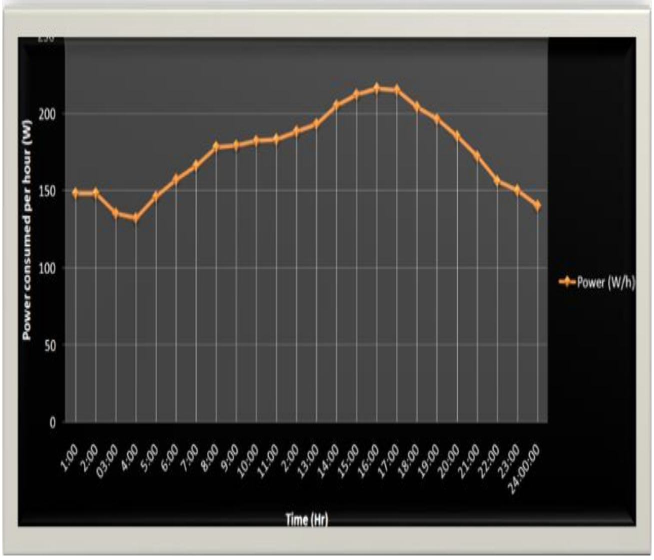

Fig 1 the Power Used in the Micro Cells

The result showed that the micro cell consumed averagely 174.4W of power everyday with an overall power usage of 4186W which computed for a month is 129766W which is 129.766KW. The cost of the power consumed in a day when computed in Naira with a kilowatt of power equal to 150.15naira. The cost when computed in naira is N193843. The energy efficiency is 60.8% which was computed using the ratio between the required power and the used power per hour. The implication of this result showed that the rate of energy and power consumed by the 4G base station is much and has directly affected the cost of service. Hence the study proposes to improve the transmission energy efficiency of the base station to help reduce the rate of energy conservation using an adaptive cell selection algorithm.

➢ *System Model*

A typical 4G cellular network structure consisting of multiple cells is considered with one Omni-directional BS providing radio access to the mobile users in each cell as shown in the schematic in Figure 1.A BS controller provides intelligence to all the BSs in the network which includes allocation of radio channels, handover decisions etc. The proposed energy saving model, every BS is considered to be accompanied with a micro base station which is capable of providing coverage to lesser area consuming only a portion of the fixed power consumed by the macro base station. Each cell will have some allocated bandwidth that must be shared between all the incoming user requests by assigning proper amount of physical resource blocks (PRB) to each user. This model is designed for serving multiple data rate requirements and the number of PRBs assigned to each user request depends on the data rate that is required for the particular service requested.

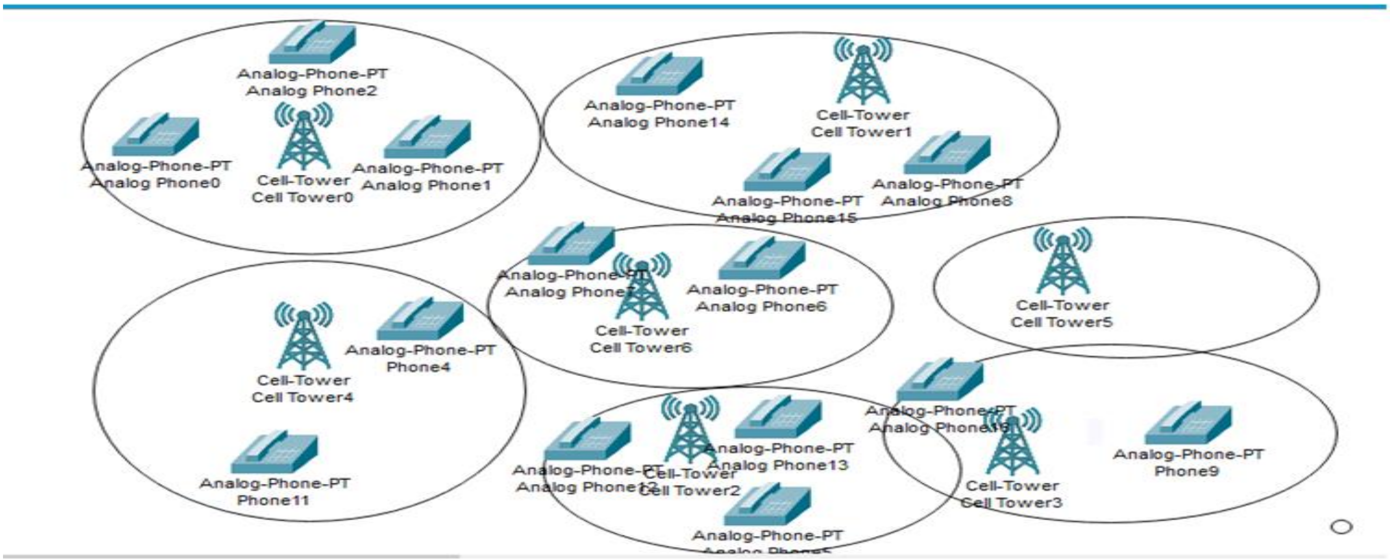

Fig 2 Cell Network Structure with Base Station Located at the Center of each Cell and Randomly Generated user for Load Equal to 3.0

In this work, a network consisting of N cells$C = \{C_1 C_2 C_3 \dots \dots \dots C_N\}$ each having a multi-base station: A macroBS and a micro BS, is assumed in a cellular region.

The macro BS are denoted as a set $B = \{B_1 B_2 B_3 \dots \dots \dots \dots B_N\}$ andmicro BS are denoted as μB = $\{\mu B_1, \mu B_2, \mu B_3 \dots, \mu B_N\}$. Thisnetwork is capable of serving a maximum of M user requestsand is denoted as U = $\{U_1, U_2, U_3, \dots \dots ., U_M\}$. A variable xis defined to indicate the association of a particular userto a particular cell.

$$xij = \begin{pmatrix} 1 \; if \; U_i \; is \; served \; by \; a \; BS \; in \; cell \; C_j \\ 0 \quad otherwise \end{pmatrix}$$

Each user request is served by a BS of only one cell at a given point of time and the BS which provides the highest QoS to the user is considered to be the one which serves that user request. Received signal strength is considered to be quantitative measure for QoS in this work. There are many factors that influence the received signal power which include interference, noise, bandwidth, transmitted signal power.

ISSN No:-2456-2165

Data rate achieved by UE j is given by:

$$R_j = \sum_{i \in C} x_{ij}.W_{ij}.log_2\left(+\frac{P_{ij}.G_{ij}}{P_{interfernce} + P_{fixed}}\right) \qquad 1$$

Where W_{ij} is the bandwidth allocated by the BS i toUE j and is equal to W/NRB,

W is the total bandwidth available for a BS,

NRB is the total number of PRBs in each BS,

P_{ij} is the transmission power assigned betweenBS i and UE j,

$G_{ij}$is the channel gain,

$P_{interfernce}$ is the totalinterference power from the neighboring BSs.

P_{noise} is theloss of power due to noise which is very less comparedto interference power in wireless cellular networks andhence is neglected in this work. The total power consumed by a base station is the combination of static power consumed by a BS which is denoted as P_{fixed} and dynamicpower used to transmit signals to the UEs that arebeing served by the BS. Power consumed by the cellularnetwork at any time instant is given by:

$$P_{tot} = \sum_{i \in C}\sum_{i \in U} x_{ij}.A_i.P_{ij} + P_{fixed,i} \qquad 2$$

Where P_{ij} is the power transmitted by BS i to serve UE j, A_i is the BS power scaling factor which includes amplifier and feeder losses, $P_{fixed,i}$ is the fixed power that is consumed by a BSi to be up and running.

The model of transmission energy efficiency using the relationship between the receiver power, the transmitter power, the gain for the transmission, reception and gain as shown below;

$$P_r = P_T \frac{G_{Tx}G_{Rx}}{4\lambda d/\lambda^2} \qquad 3$$

Where;

Pr = Receive power at distance dd from the transmitter

P_T= Transmit power
G_T= Gain of transmitting antenna
G_R= Gain of receiving antenna
λ = Wave length
d = Distance between the transmitter and receiver

- *Proposed Triplet Mode Techniques for Energy Saving Techniques*

Base station sleeping is widely used technique for energy efficient base station operation. This involves 2modes of BS operation: Active and sleep. Whenever a BS is in sleep mode, all the neighboring active BSs are responsible to serve the waiting UEs in the cell with sleeping BS. A minimum call blocking probability prevents more BSs to go into sleep mode which limits BS power conservation.

The proposed technique that was incorporated in this work will helps increase the BS power conservation by adding a low-power mode in which a micro BS capable of serving lesser area consuming very lower power is co-located with every BS.

Mode factor defines the mode of operation of a particular BS: Active, low power, sleep. Depending up on the traffic at a particular time instance t, mode factor of every BS is first calculated using Algorithm 1.

$$M_I = \begin{cases} 0 \;\; Sleep\ mode \\ 0.5\ low\ power\ mode \\ 1\ active\ mode \end{cases}$$

Once the mode of operation for all the BSs are defined, all the users who are in the cells with BS having M_I= 0 and those users who are beyond the micro BS limits inthe cell with M_I= 0.5 are marked as unserved or waitingusers. Base station controller should intelligently allocatethe unserved UEs to active BSs without compromising the QoS of any users. Whenever the given Mi values does not satisfy the overall QoS of all the UEs, Algorithm 2 is used to recalculate the $M_I$values of all the BSs in order tomake sure that QoS is guaranteed for all users.

- *Algorithm 1*

- Step 1 threshold limit for traffic load is estimated
- Step 2 Mi =0 was marked for a base station whose traffic load was below the threshold value
- Step2 Mi = 0.5 was marked for a base station whose difference of traffic load for macro and micro base station is below threshold
- Step 4: BS which does not satisfy step 2 and 3 are marked with Mi = 1

- *Algorithm 2*

- Step 1: Calculate if every BS in low-power or sleep mode have at least 2 active neighbors or else bring up the BS with highest traffic to active mode.
- Step 2: Calculate the PRBs required for unserved UEs and PRBs available with active BSs.
- Step 3: If the PRBs required is less than that of the available, bring up the necessary BSs to satisfy the condition in step 2.

ISSN No:-2456-2165

Dynamic power consumption of a BS can be reduced by intelligently allocating the UEs to the nearest BS capable of serving it which have more SINR and better QoS.

Hence allocating unserved UEs to active BSs is one of the crucial tasks for BSC. In this paper, a more efficient, easier and economic algorithm is provided for the unserved UE allocation which is summarized in Algorithm 3.

IV. RESULT AND DISCUSSIONS

The developed triplet mode techniques for Energy Saving Techniques was implemented in the java programming language. The listing of the program source code as is given in appendix A.The digital model of the case study cell network structure with base station was created using the advanced Cisco packet tracer 7.0. The packet tracer is a network modeling simulation program for the design and simulation of infrastructure (wired of wireless). It has the facilities to emulate enterprise network device, protocol and algorithms. The Cisco packet tracer program has Application Programming Interface (API) support for java and C^{++} programming language. With this program codes of algorithm (such as that of the developed triplet mode techniques for Energy Saving Techniques) can be loaded into it workspace, enabling it to interact with the kernel of the packet tracer program. The triplet mode techniques for Energy Saving Techniques interacts with the packet tracer radio network operating system object via Common Object Request Broker Architecture (CORBA).This program allows inter object communication. It allows communication between object that are written in different programming language.

To evaluate the amount of power consumption savings generated by implementing the triplet mode techniques BS switching technique for a multiple data rate environment, a cellular network consisting of 7 cells shown in Figure 3.1 is considered with each cell having a BS at the center of the cell region which is accompanied by a micro BS to maintain a low-power mode of operation. A macro and micro BS are considered to cover a region of radius 750 and 300 meters respectively.

All the technical specifications of the BSs and channel are summarized in Table 3.2. Users are allowed to request two types of services: Type 1 requires less data rate and type 2 requires high data rate. Users were randomly located in the considered 7 cell area based on uniform spatial distribution. For a given network traffic rate, Poisson arrival statistics were used to generate data at the users. The proposed algorithms then determine the BSs that are active, in low power and in the sleep mode. To analyze the power savings of this method compared to a network in which all the BSs are active irrespective of the traffic conditions in the region, both models are simulated using **MATLAB** and the results are discussed below.

During each network operation, the network traffic statistics is queried programmatically from the simulation trace file in interval of three seconds (the network performance data sampling window is 3 seconds). From the simulation trace file, the network performance statistics are extracted and plotted to evaluate the performance of the developed algorithm. From the simulation trace file the energy, are extracted, tabulated and plotted.

TABLE 2 Validation of energy saved from the develop techniques and existing techniques

Time (hr)	**Power (W/h) with al developed triplet mode techniques**	**Power (W/h) with existing algorithm**
01:00	128	148
02:00	128	148
03:00	115	135
04:00	112	132
05:00	126	146
06:00	137	157
07:00	146	166
08:00	158	178
09:00	159	179
10:00	162	182
11:00	163	183
12:00	168	188
13:00	173	193
14:00	185	205
15:00	192	212
16:00	196	216
17:00	195	215
18:00	194	204
19:00	176	196
20:00	175	185
21:00	162	172
22:00	146	156
23:00	120	150
24:00	120	140
Average	155.6	174.6

The result presented the comparative performance of the cell station with the new algorithm which has 155.6W average power and without the algorithm which has 175W as average power. The result was analyzed using the excel software and the graph is presented below;

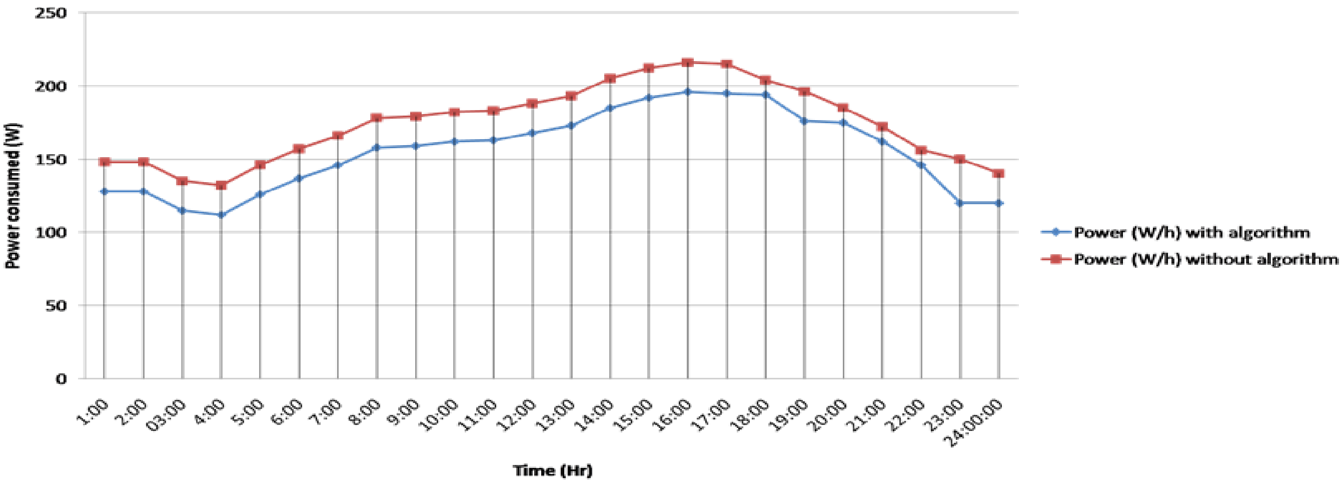

Fig 3 Comparative Result of develop Techniques and Existing Techniques

The result presented the comparative performance of the system developed with the characterized. The result showed that the BS with the new algorithm consumed less energy compared with the characterized. The percentage improvement achieved is 10.5 percentage which the conserved energy with the new algorithm. This paper proposed adaptive short route cell search algorithm in 4G network to improve power efficiency which used the reference signal receiver power technique to identify the shortest route to the destination based on the base station signal strength and deliver the packet. This will reduce power consumption in base station and improve the quality of service.

V. CONCLUSION

This research work has successfully developed an improved transmission energy efficiency algorithm to optimize throughput and reduce latency in an LTE-Advanced heterogeneous network using a developed triplet. The system was developed after series of literature reviews and then an adaptive cell selection algorithm was developed which has the ability to select the shortest route to user destination based on SINR and signal strength. This way energy was conserved and routing performance was improved.

In this work the problem of energy improvement in base transmission station was tackled using mixed integer developed triplet mode techniques optimization algorithm. The developed triplet mode algorithm was designed to optimally decide, based on the energy minimization, the user equipment to assign available channel. The objective function of the optimization algorithm designed is the minimization of energy. The constraints of the optimization include; time limit, limit on cooperating user equipment for channels. The triplet mode techniqueswas implemented in the java program language to test the performance of the developed triplet mode techniques; a digital model of a cognitive radio network environment was created using the advanced Cisco packet tracer 7.0 software. The performance of the developed algorithm was compared with that of the existing algorithm for energy improvement.

Result from simulation carried out showed the effectiveness of the developed algorithm. Comparative analysis showed that the developed The developed triplet mode algorithm outperformed the existing algorithm. Analysis of the variation of throughput with time indicates the developed triplet mode algorithm maintained the stability of throughput even with the increase in user equipment connection session. The developed triplet mode algorithm achieved higher average throughput than the existing algorithm. The developed algorithm in traffic throughput by a margin of 33.15%. The use of the triplet mode techniques for energy improvement algorithm result is far less traffic delays than the existing algorithm. It reduced the delay experienced with the existing algorithm by about 52.91%. The developed triplet mode algorithm had an effective impact in the improvement of the utility of the radio network resource. It realized a higher rate of system resource utilization over the existing algorithm. The average utility of the network resource using the developed method is 71.02%, while that of the existing algorithm is 59.5%. This shows the triplet mode techniques achieved 11.52% improvement over the existing algorithm in resource usage. The triplet mode techniques algorithm reduced the energy usage of the existing by 24.98%. The lower the energy used by the triplet mode techniques showed that it is more versatile and efficient than the existing algorithm.

REFERENCES

[1]. Wu, J.; Zhang, Y.; Zukerman, M., "Energy-efficient base-station sleep-mode techniques in green cellular networks: A survey.", IEEE Commun. Surv. Tutor. 2015, 17, 803–826.
[2]. Fehske, A.; Fettweis, G.; Malmodin, J.; Biczok, G., "The global footprint of mobile communications: The ecological and economic perspective", IEEE Commun. Mag. 2011, 49, 55–62.
[3]. Hasan, Z.; Boostanimehr, H.; Bhargava, V.K., "Green cellular networks: A survey, some research issues and challenges", IEEE Commun. Surv. Tutor. 2011, 13, 524–540

[4]. Sharma GHTY (2013), “Networks and devices for the 5G era”, IEEE Communications Magazine 52 (2), 90–96.
[5]. Ch´avez-Santiago, R., Szydelko, M., Kliks, A., Foukalas, F., Haddad, Y., Nolan, K. E.,Kelly, M. Y., Masonta, M. T., Balasingham, I., (2015), “5G: The convergence of wireless communications”/, Wireless Personal Communications 83 (3), 1617–1642.
[6]. M. F. Hossain, K. S. Munasinghe and A. Jamalipour, “On the energy efficiency of self-organizing LTE cellular access networks,” IEEE Global Communications Conference, Anaheim, CA, pp. 5314-5319, December 2012
[7]. Mogensen, P., Na, W., Kováes, I. Z., Frederiksen, F., Pokhariyal, A., Pedersen, K. I., … Kuusela, M. (2017), “LTE capacity compared to the shannon bound”, IEEE Vehicular Technology Conference, (1), 1234–1238. http://doi.org/10.1109 /VETECS .2007.260
[8]. Jie Gong, Sheng Zhou and Zhisheng Niu, “A dynamic programming approach for base station sleeping in cellular networks,” IEICE Transactions on Communications, Vol. E95-B, No.2, pp. 557-562, February 2015.
[9]. Peng, M., Liang, D., Wei, Y., and Li, J. (2013). Self-Configuration and Self-Optimization in LTE-Advanced Heterogeneous Networks, (May), 36–45.
[10]. Jiyong et al and Rathi, S., Malik, N., Chahal, N., and Malik, S. (2014), “Throughput for TDD and FDD 4 G LTE Systems”, (12), 73–77. Report, T. (2013). ETSI TR 125 996, *0*, 0–41.
[11]. Micallef, P. Mogensen and H.-O. Scheck, “Cell size breathing and possibilities to introduce cell sleep mode,” European Wireless Conference, Lucca, pp. 111-115, April 2010.
[12]. Feng, M.; Mao, S.; Jiang, T., “BOOST: Base station on-off switching strategy for energy efficient massive mimo hetnets”, In Proceedings of the 35th Annual International Conference on Computer Communications, IEEE INFOCOM 2016, San Francisco, CA, USA, 10–14 April 2016; pp. 1395–1403