



# Deploying 3-Stage Switch Mode Technique at Base Stations to Optimize Energy Consumption in Wireless Communication Networks

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Abstract

Original Research Article

This work focused on the deployment of a 3-stage mode technique at base station to optimize energy consumption in wireless communication network. Due to the high operating costs of traditional wireless cellular networks and the scarcity of energy resources in low-power applications, the anticipated increase in wireless communication traffic has forced the development of Energy Efficient (EE) techniques for the design of wireless communication systems. With the goal of increasing energy efficiency at the base station level for future generation networks, the base station is the center of bulk energy use in light of current energy issues. In order to improve energy efficiency at the base station level, this work investigated several methods of implementing energy-efficient procedures. It also looked at paradigm shifts by employing switch mode approaches. The research adopted three switch modes techniques. Three switching stages were considered namely, Sleep mode, Safe mode, and ON modes. With the three-switch mode technique, the energy efficiency was improved from significantly when compared with the two switch modes technique.

**Keywords:** Energy efficiency, switch modes, Base station, sleep mode, safe mode, Network.

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## 1.0 INTRODUCTION

The design and functioning of wireless communication technology now heavily depend on energy usage. Without a doubt, communication networks have been developed for more than a century with the intention of enhancing performance metrics like latency, throughput, and data rate. However, because of operational, environmental, and economic concerns, energy

efficiency has emerged as a new key figure of merit in the last ten years (Hammi, 2015).

Since mobile communication networks make for a significant portion of the total energy consumption of information and communication technology, declining mobile communication network energy consumption has drawn a lot of attention. Rising energy utilization is a major worry associated with global warming. The base station of a wireless



network uses the majority of its energy (Wu et al., 2015). There are several benefits to energy efficiency, such as reduced domestic and economic costs, fewer greenhouse gas emissions, and a reduced need for imported energy. Energy efficiency will therefore be one of the most important factors in the construction of the next generation of wireless networks. Future generation systems will undoubtedly support an unprecedented number of devices, offering new and rate-demanding services together with constant connectivity. According to projections, there will be more than 50 billion connected devices by 2030 (Ericsson white paper, 2011), or more than six connected devices per person, encompassing both machine-type and human-type connections.

## 2.0 THEORETICAL ANALYSIS

One of the main issues related to global warming is increased energy consumption, and since mobile communication networks account for a significant portion of the total energy consumption of information and communication technology, reducing their energy expenditure has received a lot of attention. Energy production has detrimental effects on the environment, including global warming, and is costly for both operators and consumers. Since mobile communication networks account for a large portion of the world's energy consumption, reducing their energy consumption has attracted a lot of attention (Lee et al., 2013). New methods for designing and operating wireless networks are needed to minimize energy consumption and protect the environment. To improve average performance, energy efficiency should also be utilized. With the growing advancements in mobile Internet access and delivery, 5G wireless networks are a significant communication technology for ubiquitous connection in the near future. Reducing energy consumption has drawn a lot of attention since mobile communication networks use a significant portion of the total energy used by information and communication technologies.

New strategies for wireless network design and operation are required to avoid the energy crisis. In

the wireless academic and industrial sectors, there is broad agreement that the 1000× capacity expansion must be accomplished with a power consumption that is comparable to or less than that of current networks (NGMN alliance, 2015). This suggests that a factor of at least 1000 must be added to the efficiency with which each Joule of energy is used to transport data. In order to improve network energy efficiency, the GreenTouch consortium was established in 2010 as an open worldwide pre-competitive research cooperative ("The GreenTouch Project," 2016).

One of the main issues associated with global warming is the continuous increase in energy consumption. Since mobile communication networks account for a sizable portion of the total energy consumption of information and communication technology, reducing their energy consumption has attracted a lot of attention. The impact of mobile communication network energy consumption will become more severe as future generation networks are expected to have higher traffic loads. The base station (BS), which is the main energy user in mobile communication networks, is influenced by traffic load, which varies with location. Although a lot of work has been done to reduce the energy usage of mobile communication networks, much more has to be done in terms of BS energy savings. Turning off as many of a BS's components as possible when they are no longer required or in operation is the fundamental idea behind lowering its energy consumption. Simply shutting off the energy to the majority of the base station's components while not in use will put it to sleep. A BS can be shut down to significantly reduce energy consumption if there is little traffic on it and the traffic can be handled by nearby BSs (Jahid et al., 2016). However, as neighboring BSs with overlapping coverage can also service the user equipment (UEs) covered by the central BS, the central BS can be turned off to save energy while neighboring BSs serve the UEs. Future wireless networks should be more energy-efficient for a number of reasons, including design concerns, green technology regulations, company cost savings, end user satisfaction, and national development.

The majority of the energy used by wireless devices is transformed into heat, which presents issues for governments, end users, and equipment use. By implementing energy-efficient protocols, this effort will reduce the amount of heat produced by wireless devices in base stations. Additionally, since the devices will generate less heat, less energy would be needed to run the base stations and maintain the temperature of the surrounding area. Thus, the issue of energy loss through heat is eliminated or minimized. Second, with regard to green technology policy, the majority of countries worldwide are currently grappling with an energy crisis. Society is also concerned about environmental issues, such as the issue of greenhouse gas emissions. More greenhouse gasses are produced when more energy is used. This project would provide the world with energy-efficient 5G base stations, which would lower the world's overall energy usage.

In order to join Nigerian markets, providers of next-generation wireless networking must have their products certified for the statutory requirements of low energy usage. They may be able to obtain energy-efficiency certifications more easily if they use energy-efficient wireless network equipment. Because they pay based on the quantity of energy utilized, it would result in lower operating expenses for the operators. When sending or receiving wireless signals, base stations need a lot of energy. The service provider could be able to reduce electricity costs. For future generation networks to

attain good energy efficiency, seven key areas need to be improved. The minimization of needless state changes and the addition of a more recent Radio Resource Control (NRRC) state for setting signaling are two of the most noteworthy areas. Enhancing base station energy efficiency is the second objective. Achieving energy efficiency while keeping an eye out for possible interference is the third objective.

The components of a network base station system and their power consumption must be investigated in order to comprehend the issues with cellular BS power consumption. The 5G network system with support for multiple transmit antennas is the desired system for the base station efficiency analysis; however, this work will limit the study to four (4) transmit antennas per sector. This system can attain high data throughputs by taking use of the space domain. A macro cell base station with three (3) sectors and four (4) parabolic reflect transmit antennas per sector was taken into consideration in the study. The Effective Radiated Power (ERP) of each parabolic transmit antenna is intended to be 67dBW. As a result, each macro cell base station needs twelve (12) Power Amplifiers (PA) and antennas due to the four (4) transmit chains used for the four (4) antennas. Each micro cell base station at the micro cell level is made up of an isotropic antenna that radiates energy inside the cell of coverage.

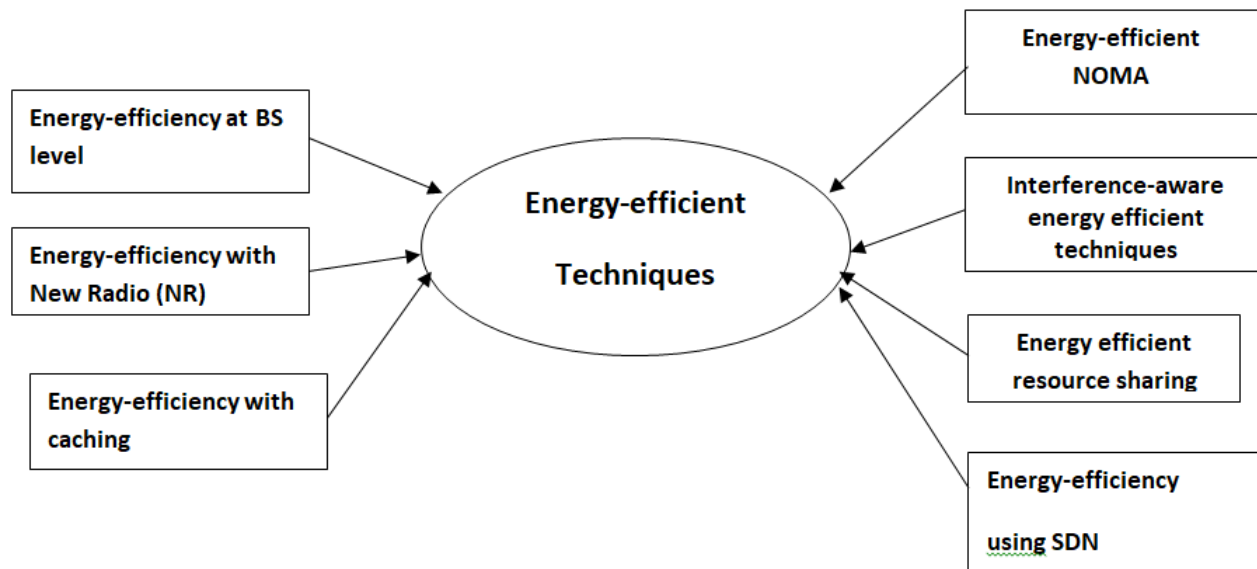


Figure 1: Outline of the energy-efficiency schemes ( Nwaogu., 2023).

### 3.0 MATERIAL AND METHODS

The materials used for the work include: (i) Baseband signaling unit/ Baseband (BB) interface: ii) Antenna/Antenna interface (AI): (iii)

Mains Power supply unit (iv) RF chains (v) Power amplifier (vi) Cooling unit (vii) Network analyzer (viii) User equipment modules, (ix) Software tools used (Mathlab/ Simulink 2023a )

#### System Setup for Base Station Switching States

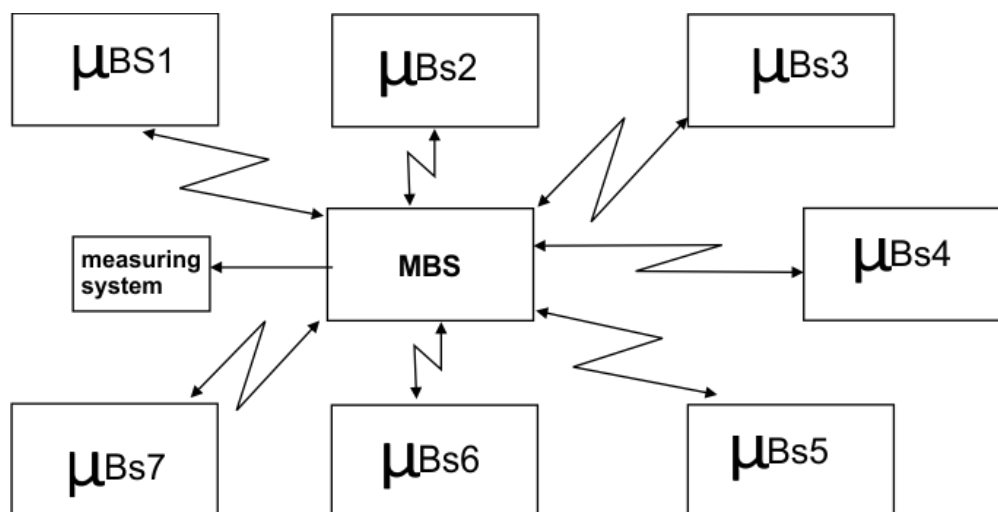
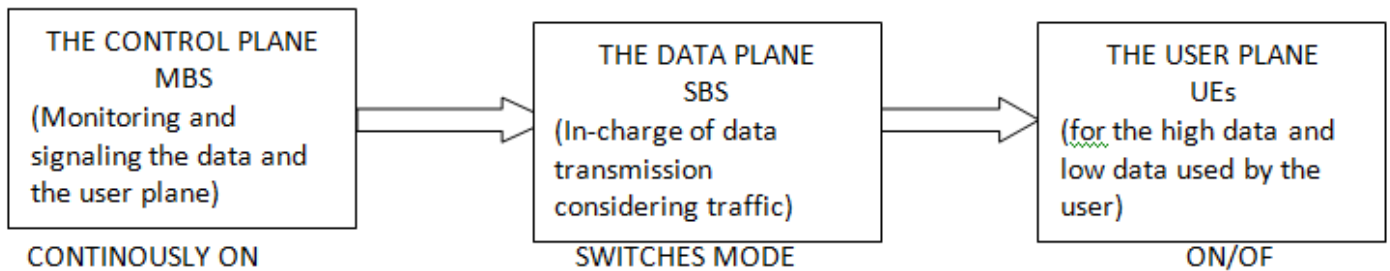


Figure 2. Block diagram showing system setup of base station switching

Figure 2 represents a system set up of a heterogeneous network cluster is made up of seven micro cells. There is a control and data plane. In the cluster the macro cell base station (MBS) serves as the control plane and is designed to be ON permanently in the network, while the micro cell base stations ( $\mu$ BS) is in charge of the data

transmission in each cell and around its neighbourhood. The micro cell base stations are design to switch modes between ON, SAFEMODE and SLEEP modes depending on the traffic. The MBS controls the  $\mu$ BS on when to switch ON, SAFEMODE or SLEEP modes through the Radio Access Technology (RAT) located on the MBS.



**Figure 3: Block Diagram showing the stages in Proposed Energy saving scheme**

Figure 3 illustrates the three levels of the switch mode system employed in the study: the control plane, the data plane, and the user plane. The macro cell base station (MBS) is part of the control plane. This stage is designed to run continuously for twenty-four hours. In order to signal the  $\mu$ BS to turn on, switch to SAFE mode, or go into SLEEP mode, the control plane keeps an eye on the data plane. The small cell base stations make up the data plane. Data transfer is under its control. Hence considering

the traffic/ the number of connectivity of user equipment, it could be ON, SAFE mode or SLEEP mode. At this stage saving of power could be achieved. The User plane is the stage where all the high data consuming and low data consuming devices are located. They could be ON or on SLEEP (dormant) mode, they could be mobile or statically located. They are also monitored by the control plane as well, while the data plane handles the data.

Equation (1) can be used to determine the overall amount of energy used daily by base stations in a cluster, allowing for the computation of the system's energy efficiency while taking peak and off-peak periods into account.

$$E_{cons}^{day} = \sum(K_{BS}^{active} * U_{op}^{BS}) * hour \tag{1}$$

Where  $E_{cons}^{day}$ = energy consumed per day  $K_{BS}^{active}$ = number of active base stations  $U_{op}^{BS}$ = Power consumed by the base station when it is on, “hour”= The number of hours in the day it operated.

$$E_{cons}^{day} = P_{tot} * time \tag{2}$$

$$P_{tot} = P_a + n(P_{\mu on} + P_{\mu sleep} + P_{\mu sfm}) + P_{transition} \tag{3}$$

where  $P_{tot}$  is the total power used by each cluster in the network.  $P_a$  is the macro cell base station's power consumption,  $P_{(\mu ON)}$  is the small cell base station's total power consumption while it is in ON mode, and  $P_{(\mu sleep)}$  is the micro cell base station's total power consumption when it is in sleep mode. While  $n$  is the number of micro cell base stations that are operational at a given time,  $P_{(\mu sfm)}$  is the total power used by the small cell base station when it is in safe mode.  $P_{transition}$  is the overall amount of power used by the base station during a state transition. We assume that every user device in the cluster that a macro base station covers receives a control signal from the macro base station. Second, all micro base stations in a cluster are thought to have the same maximum power rating.  $\beta_{ij}$  represents the connections between a micro base station ( $M_i$ ) and user equipment. Equation 3 illustrates this.

$$\beta_{ij} = \begin{cases} 1 & \text{If } V_j \text{ is connected with } m_i \text{ (} 0 \leq i < k+1, 0 \leq j < n \text{)} \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

$$t_r = \begin{cases} 1, & \text{If } V_j \text{ request for service, (} 0 \leq i < n \text{)} \\ 0, & \text{otherwise} \end{cases} \tag{5}$$

In equation (5) above,  $t_r$  represents the data service request of user equipment  $V_j$ . The data rate as a result of traffic is denoted as  $r_i$  and it is shown in equation (6).

$$r_i = \begin{cases} 1, & V_j \text{ requires high data rate} \\ 0, & V_j \text{ requires low data rate} \end{cases} \tag{6}$$

In equation (7)  $A_j$  is related with whether  $M_i$  is in ON state or not while in equation (8),  $E_j$  is related with whether the  $M_i$  is in safe mode (sfm) or not. Equation (9)  $F_j$  is related with whether  $M_i$  is in sleep state or not

$$A_j = \begin{cases} 1 & \text{if } M_i \text{ is in on state} \\ 0 & \text{otherwise} \end{cases}, (0 \leq j < g + 1) \tag{7}$$

$$E_j = \begin{cases} 1 & \text{if } M_i \text{ is in sfm state} \\ 0 & \text{otherwise} \end{cases}, (0 \leq j < g + 0.5) \tag{8}$$

$$F_j = \begin{cases} 1 & \text{if } M_i \text{ is in sleep state} \\ 0 & \text{otherwise} \end{cases}, (0 \leq j < g) \tag{9}$$

The state transitions of a micro cell base station are expressed using  $X_j$  for transition between on and off,  $D_j$  for transition between safe mode and on modes and  $Q_j$  for transition between sleep mode and safe mode. Their values are as shown in equations (10); (11) and (12);

$$X_j = \begin{cases} 1, & \text{if } M_i \text{ switches between on state and off state} \\ 0, & \text{otherwise} \end{cases}, (0 \leq j < g + 1) \quad (10)$$

$$D_j = \begin{cases} 1, & \text{if } M_i \text{ switches between Sfm and on state} \\ 0, & \text{otherwise} \end{cases} (0 \leq j < g + 0.5) \quad (11)$$

$$Q_j = \begin{cases} 1, & \text{if } B_i \text{ switches between sleep mode and safe mode} \\ 0, & \text{otherwise} \end{cases}, (0 \leq j < g) \quad (12)$$

Using the above equations the power consumption of an  $M_i$ ,  $P_{(mj)}$  is obtained as in equation (13):

$$P_{(mj)} = Z_j * (1 - F_j) * (P_{\mu o} + g_s * P_{\mu o}^{tx}(j)) + F_j * (1 - E_j) * P_S^e + E_j * \frac{(1 - F_j)}{2} * (P_{\mu o} + g_s * P_{\mu o}^{tx}(j)) \quad (13)$$

while a micro cell base station is in the ON state, the power consumption is computed as the steady sum of the power consumed and the load-dependent power consumption; while it is in the safe mode, the calculation is based on the power consumption in that mode. If a micro cell base station is in sleep mode, the power consumption in that mode is utilized for the computation, and the power amplifier consumption is in the intermediate. Equation (14) displays  $P_{\mu o}^{tx}(j)$  is with respect to load-dependent power consumption.

$$P_{\mu o}^{tx}(j) = P_{\mu o}^{tx,max} * \sum_0^{k-1} \left( tr * \beta_{ij} * \frac{(r_i * c_{max} + (1 - r_i) * c_{min})}{c_{\mu}^{max}} \right) \quad (14)$$

The power consumption of the macro base station ( $P_a$ ) could be calculated using equation 15. Where  $P_{amax}^f$  is the maximum fixed power of the macro cell base station,  $g_m$  is the power gradient of the macro cell base station and  $P_a^{tx}$  is the transmit of the macro cell base station

$$P_a = P_{amax}^f + g_m + P_a^{tx} \quad (15)$$

Where the value of  $P_{amax}^f$  is as shown in equation (16)

$$P_{amax}^f = P_a^{tx,max} * \sum_0^{k-1} \left( tr * \beta_{ij} * \frac{(r_i * c_{max} + (1 - r_i) * c_{min})}{c_{\mu}^{max}} \right) \quad (16)$$

During modes/states transition of the micro cell base station  $\mu$ BS,  $P_{transition}$ , is calculated using equation 16

$$P_{transition} = \sum_0^{k-1} (X_j * (1 - D_j) * P_{on-off} + D_j * (1 - Q_j) * P_{sfm-on} + Q_j * (1 - X_j) * P_{sleep-sfm}) \quad (17)$$

$$P_{amax} = P_a + P_{transition} \quad (18)$$

The maximum energy consumption of an MBS is  $P_{amax}$  and thus the power consumption of a Macro cell base station during off peak  $P_a$  should be less than  $P_{amax}$ ,

#### 4.0 RESULTS AND DISCUSSION

The results of the simulations are discussed in this sections

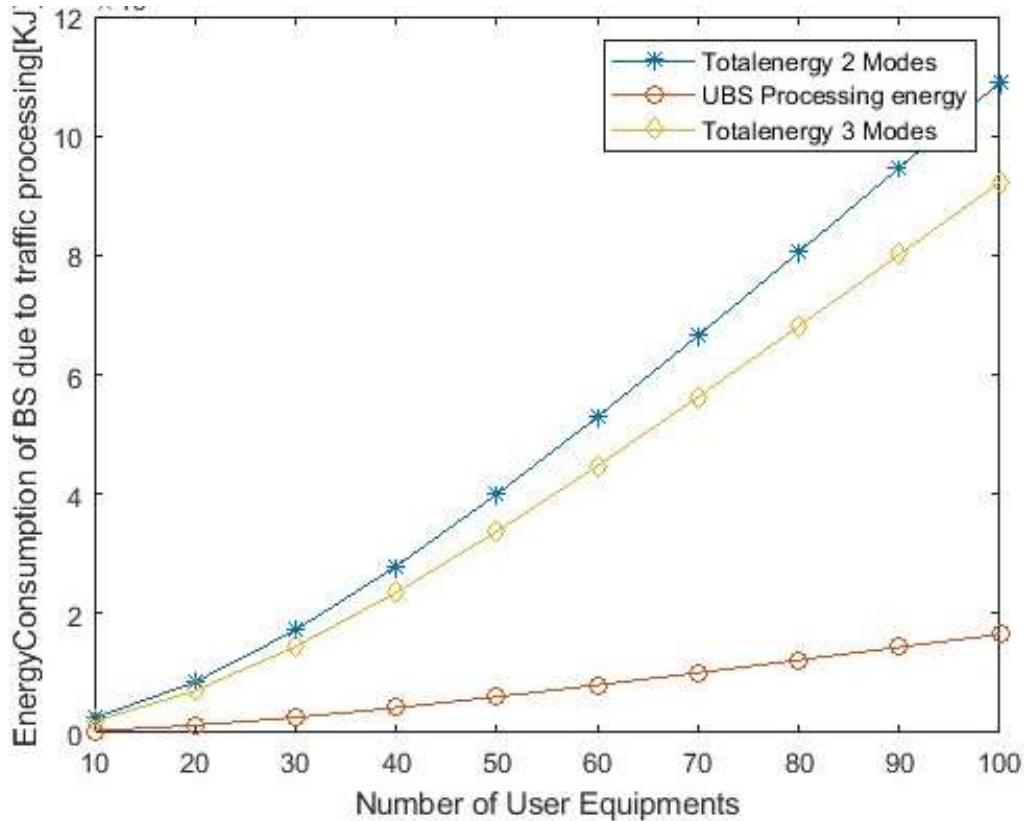


Figure 4: Energy consumption of user equipment due to traffic processing

The total energy consumption of  $\mu$ BSs resulting from traffic processing utilizing 2-modes and 3-modes switching systems is displayed in Figure 4, along with the total energy of  $\mu$ BSs corresponding to an increase in the number of user equipment connected to the network. When compared to the suggested three switch modes approach in this work, it is evident that the two modes system uses more energy. Second, the number of user equipment connected to the network determines how much energy the cluster BSs consume overall. The impact of traffic on base station energy consumption shows

that a three-mode scheme performs better than a two-mode scheme, improving the system's energy efficiency.

As the number of micro cell base stations ( $\mu$ BSs) varies, Figure 5 displays the energy usage during traffic processing in joules (J) for the two modes and three modes schemes, respectively. It is evident that fewer base stations are connected during off-peak traffic times, and the two designs' energy usage is nearly similar. Both the number of  $\mu$ BSs and the overall amount of energy consumed rise with traffic.

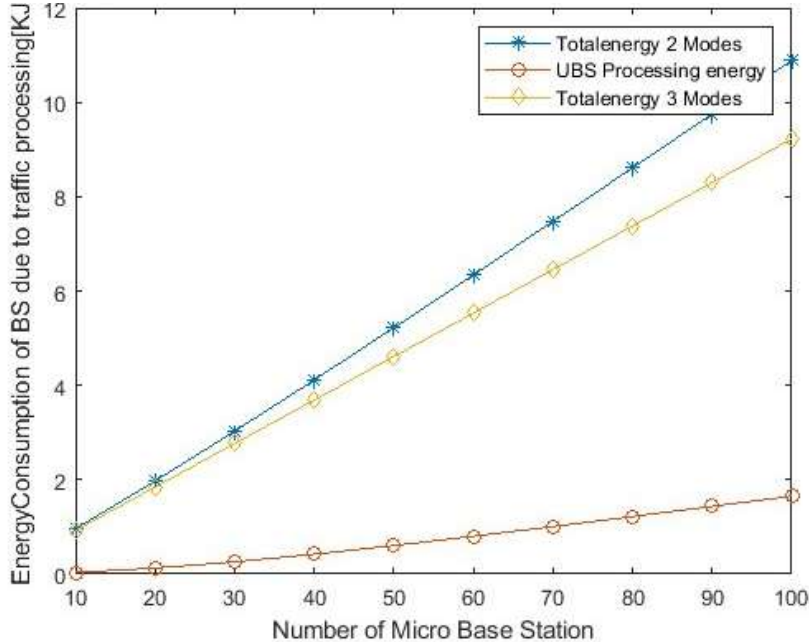


Figure 5: Total energy consumption of BS due to traffic processing(M-file Appendix V)

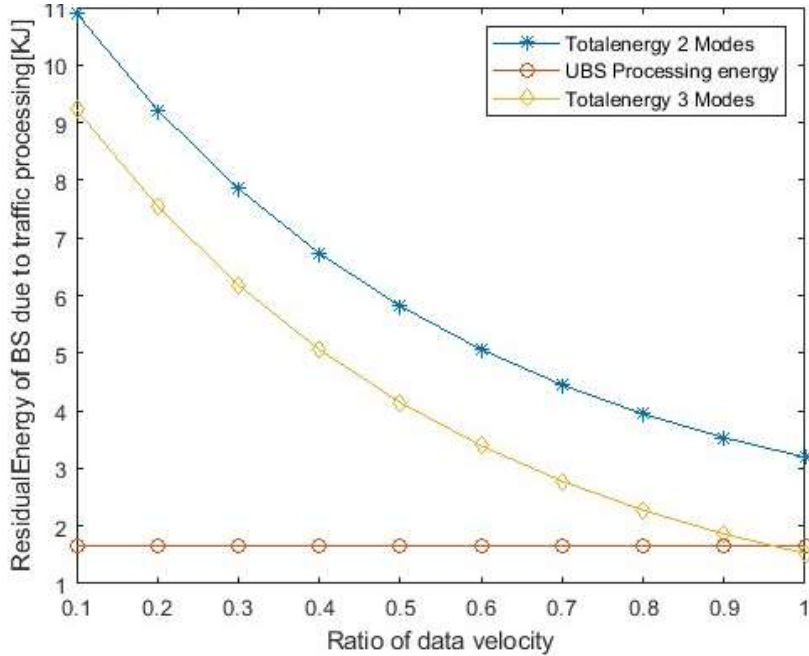


Figure 6: Residual Energy due to traffic processing (M-file Appendix V)

Figure 6 shows the average residual energy versus the rate of transmit data measured at continuous (regular) intervals of a network using the three modes and the two modes scheme. From figure 6

the residual energy for the three modes scheme is less than that of the two modes scheme. To extend wireless network lifespan, there is a need for efficient energy control mechanisms to reduce

energy intake at the base station level. At the same time, energy efficient methods should be deployed at all layers of the network which should be proportional to changes in traffic.

## 5.0 CONCLUSION

Seven cellular clusters were created in a heterogeneous environment. A modified tiny cell and a three-stage switch mode scheme (ON, SAFE, and SLEEP) were used in the design of each cluster. With the addition of distinct control and data planes, this three-stage switch method was suggested for a heterogeneous network. In order to reduce power during low or regular traffic hours, this energy-saving strategy has a threshold when the small cells ( $\mu$ BS) switch to SLEEP, SAFE, or ON utilizing a switch mode. This program increased energy efficiency by 21.47%. The plan produced positive simulated results and can be used to address the problem of energy usage.

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