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Development of an Improved Dynamic Algorithm to Enhance Energy Saving in Long Term Evolution Mobile Access Networks

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Abstract

This paper presents a dynamic algorithm for improving energy saving in Long Term Evolution (LTE) mobile access networks through off mode, sleep mode and multi-cell cooperation utilization at the eNodeBs. The dynamic energy saving algorithm is an integration of two algorithms, namely: energy estimation algorithm and load/traffic sharing algorithm. The energy estimation algorithm estimated the energy consumption of the eNodeBs when they are powered on, irrespective of their traffic loading. The load/traffic sharing algorithm transfers traffic between eNodeBs which enabled the off mode, sleep mode and multi-cell cooperation of the eNodeBs. The dynamic energy saving algorithm were implemented in MATLAB 2013b environment. The performance of the energy saving algorithm was done by simulation. The energy saving was analysed for call blocking probability of 0.001%, 0.01% , 0.1%,1%, and 10%, while varying the energy load proportionality constant which ranges from 0 to 1 at an interval 0.1. The optimum energy saving in the network was achieved while maintaining a call blocking probability of 1% which corresponded to 51.84%, 49.82%, 46.08%, 44.35%, 41.14%, 34.71%, 28.03%, 22.95%, 17.95%, 13.34% and 7.56% for the energy-load proportionality constant of $0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9$ and 1respectively. Validation of the proposed algorithm was carried out by comparison with the always-on algorithm and the eco-inspired sleep-wake algorithm. The result showed that the proposed energy saving algorithm achieved the highest energy saving of 51.84% and 11.84% with respect to the always-on algorithm and eco-inspired sleep-wake algorithm respectively, while guaranteeing a call blocking probability of 1% at an energy-load proportionality constant of 1.

Key words: LTE Network, Load Utilization Factor, Bandwidth Efficiency, Data rate and Signal-to-interference-noise-ratio

Introduction

The LTE standard was developed by the 3rd Generation Partnership Project (3GPP) to cope with the rapid increase of mobile data usage [1]. The energy consumption as well as CO_2 footprint of mobile cellular networks are increasing at an alarming rate due to the exponential growth in mobile data traffic[2].This is because current cellular networks are typically designed and operated to meet a given coverage and capacity level by considering the peak traffic demand, while energy efficiency takes a minor (or no role at all) at the design and operation stages [3]. Consequently, minimization of energy consumption at base stations will considerably enhance the energy efficiency of LTE cellular networks [4]. Remarkably, contemporary base stations have a high-degree of non-load-energy proportional consumption characteristic and consume significant amount of energy even at no-load condition [5]. On the other hand, cellular mobile network traffic exhibits a high-degree of temporal-spatial diversity, which means that traffic demand varies both in time and space [6]. This variation is directly related to the random call making behaviour and mobility pattern of the mobile stations [7]. However, under the current network operation approach, all base stations are kept powered on irrespective of traffic load [8].This traditional network operation and the aforementioned non-load-energy proportional utilization at base stations are the major causes behind the substantial amount of energy wastage in existing cellular networks [9]. Thus, it is imperative to exploit the non-load-energy proportional utilization of eNodeBs to devise techniques to manage the energy consumption of LTE mobile access networks more efficiently [10]. Switching-off eNodeBs during low traffic situations has been proposed for future LTE systems, however the standard so far does not specify implementation schemes [11]. This is the primary focus of green cellular communication which finds radio networking solutions that can greatly improve energy saving and resource efficiency without compromising the quality of service of mobile stations [12].

Related Work

Given the nature of energy wastage, natural traffic diversity and the exponential traffic growth trend, it is crucial to develop dynamic algorithms to improve energy saving in LTE mobile access networks. The following presents a review of similar research works:

In paper [13] the author Zhouet al.,developed a centralized and decentralized ‘greedy’ algorithms for dynamic base station energy saving in green mobile access network using the base station switch off scheme. The centralized greedy algorithm utilized the complete channel information and traffic requirement of the network to determine the base station on-off states. The decentralized algorithm was used to relax the information requirement of the centralized algorithm by triggering user-specific base station according to the maximum utility function (normalized traffic load) and the protection margin for load balancing. However, the algorithm provided no strategy for turning on the base stations during high traffic demand leading to it incompatibility for self-organizing networks.

In paper [14] the authordeveloped a centralized and distributed cell zooming algorithms for cost-efficient green cellular networks. The developed dynamic cell zooming algorithms adaptively adjusted the cell size according to traffic load, user requirements and channel conditions to minimize the energy consumption of base stations and call blocking probability of users. However, the algorithms were not developed based on a power consumption model for a base station that depended on its utilization. Instead, the fixed power base station consumption model was used which resulted in energy wastage during low traffic times.

In paper [15] the authordeveloped a distributed wake-up scheduling algorithm for base stations in green cellular networks. The distributed wake-up scheduling algorithm for the base stations use three different modes of operation: off mode, sleep mode and active mode. The algorithm dynamically takes decision on its operation mode according to the measured traffic load of itself and its neighbourhood base stations in a distributed manner. However, the power consumption of the base station was not modelled as a function of its traffic utilization and the quality of service of the mobile station was not guaranteed while achieving the energy saving.

In paper [3] the author developed a distributed dynamic algorithm for both switching on and off base stations using the average system load as the algorithm initiator. The algorithm utilized communications among neighbouring base stations for exchanging load information and disseminating the switching on/off decisions. However, a more efficient algorithm is expected as the presented one does not implement any intelligence in finding the best subset of neighbours for distributing traffic leading to reduced energy savings. Also, the algorithm was developed based on an assumed fixed power consumption model instead of considering a power consumption model for base station that depends on its utilization.

In paper [16] the author Hossain et al.,developed a distributed cooperative algorithm with load balancing for improving the energy saving of LTE cellular access networks. The algorithm was developed based on the principle of self-organizing network. The algorithm used the network traffic to allow the mutual cooperation of eNodeBs for distributing traffic among themselves and thus, dynamically adjusting the number of active eNodeBs for energy saving. However, the algorithm allowed highly loaded eNodeBs to share load with their neighbouringeNodeBs and consequently increase the burden of the neighbouringeNodeBs. This led to higher traffic threshold of neighbouringeNodeBs and reduction of the possibilities of energy saving.

In paper [17] the authordeveloped a greedy-heuristic algorithm for dynamic base station planning with power adaptation for green wireless cellular networks. The algorithm switched base stations on/off and adaptively adjusting their transmission power according to the current traffic conditions. The problem of saving energy and minimizing the on/off transitions of base stations was formulated using a non-linear programming model for the green dynamic base station planning to find the best possible topology which minimizes the energy consumption of the network while satisfying the quality of service measured in terms of blocking probability and outage probability. However, the algorithm was developed by assuming that mobile users are placed as chunks like group of workers in a floor of a building which is infeasible in practical scenario. Thus, the mobile stations were not modelled individually.

In view of the imperfection associated with the reviewed work, there is a need to develop a robust dynamic energy saving algorithm for LTE mobile access networks that will incorporate the load-proportional power consumption model of eNodeBs and allowing all eNodeBs under a cluster coordinate with others to turn off/sleep the least loaded eNodeBs through load sharing with any moderately loaded eNodeBs. The proposed algorithm is expected to improve the energy savings while guaranteeing the quality of service offered to the mobile stations using off mode, sleep mode, active mode and multi-cell cooperation utilization of eNodeBs.

Proposed System

The eNodeB power consumption model is used for evaluating the energy consumption of an LTE cellular network. The eNodeBs are modelled to consume power that is partly constant and partly varies with the load factor at any given instant of time. The mathematical representation of the instantaneous power consumed by the jth eNodeB is given as [16]:

$$P_j(t) = \begin{cases} (1-q)\rho_j(t)P_j^a + qP_j^a \ ; \ active\ mode \\ P_j^s \ ; \ sleep\ mode \\ 0 \ ; \ off\ mode \end{cases} \qquad (1)$$

Where: $P_j(t)$is the operational power of the jtheNodeB at time t;$P_j^a$is the maximum operational power of the jth eNodeB;$\rho_j(t)$is the load utilization factor of the jtheNodeB at time t and$q \in [0,1]$is called the energy-load proportionality constant of the eNodeBs which determines the level of dependency of the operational power of an eNodeB on it load utilization factor.

The operational power, P_j^a of the jth eNodeB is given as [18]:

$$P_j^a = AP_{TX,j} + B \qquad (2)$$

The sleep mode power, P_j^s consumed by the jth eNodeBis given by as [18]:

$$P_j^s = qB \qquad (3)$$

Where: $P_{TX,j}$is the transmit power of the jth eNodeB;The parameters 'A' and 'B' are termed as the power profile parameters [18].

The load utilization factor at the jth eNodeB, $\rho_j(t)$at time$t$ is given as [19]:

$$\rho_j(t) = \frac{N_{used,rb,j}(t)}{N_{rb,j}} \qquad (4)$$

Where: $N_{used,rb,j}(t)$is the number of used physical resource block at the jth eNodeB at time t; $N_{rb,j}(t)$is the number of available resource block at the jth eNodeB.

Also, the number of used physical resource block at the jth eNodeB at time t is given as [19]:

$$N_{used,rb,j}(t) = \sum_{i=1}^{N_u} z_{i,j}(t) w_{i,t}(t) \qquad (5)$$

Where:$z_{i,j}(t)$ is an assignment indicator variable which is equal to 1 when ith mobile station is served by jth eNodeB at time t and zero otherwise; $w_{i,t}(t)$ is the approximate number of physical resource block allocated by the jth eNodeB to the ith mobile station at time t.

The approximate number of physical resource block allocated by the jth eNodeB to the ith mobile station at time t is given as [16]:

$$w_{i,t}(t) = \frac{R_{i,j}(t)}{W_{RB}\, e_{i,j}(t)} \qquad (6)$$

Where: W_{RB} is the bandwidth per physical resource block and it is$180\ kHz$; $R_{i,j}(t)$ is the bit rate requirement of the ith mobile station from the jth eNodeB at time t; $e_{i,j}(t)$ is the average bandwidth efficiency of the ith mobile station from the jth eNodeB at time t.
The average bandwidth efficiency of the ith mobile station from the jth eNodeB at time t is usually expressed using equation (7) when considering adaptive modulation and coding [16]:

$$e_{i,j} = \begin{cases} 0\ if\ \gamma_{i,j} < \gamma_{min} \\ \xi \log_2(1+\gamma_{i,j})\ if\ \gamma_{min} \le \gamma_{i,j} < \gamma_{max} \\ e_{max}\ if\ \gamma_{i,j} \ge \gamma_{max} \end{cases} \qquad (7)$$

Where: $0 \le \xi \le 1$ is the attenuation factor accounting the implementation loss;γ_{min} is the minimum signal-to-interference-noise-ratio; γ_{max} is the maximum signal-to-interference-noise-ratio; e_{max} is the maximum bandwidth efficiency and $\gamma_{i,j}(t)$ is the instantaneous received signal-to-interference-and-Noise ratio of the ith mobile station from the jth eNodeB.
The simulated traffic arrival pattern of an eNodeB follows a poisson distribution model given as [20]:

$$\boldsymbol{A(t)} = \frac{p(t,\mu)}{\max[p(t,\mu)]} \qquad (8)$$

$$p(t,\mu) = \frac{\mu^t}{t!} e^{-\mu} \qquad (9)$$

Where: $\boldsymbol{A(t)}$ is normalized traffic at time t, p is thepoisson distribution function, t is the specific time in a day and μ is mean value where peak number of traffic occurred.
Fig.1 shows the approximate traffic arrival pattern of a real traffic arrival pattern in a cell with a mean value of 15 [20]. Thus, the peak traffic rate during a day occurs at 3:00pm

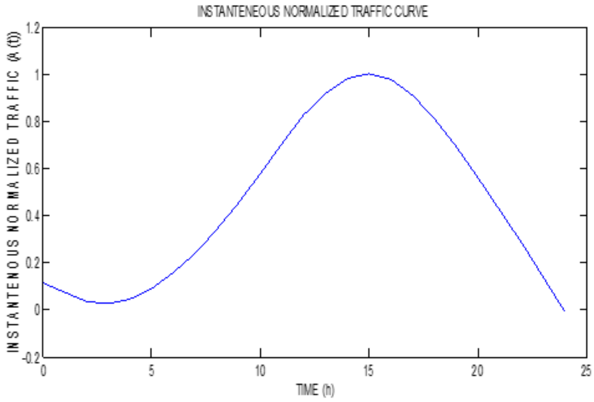

Fig.1. Instantaneous Traffic Normalization Factor

The load factor of each eNodeB in the LTE access network is normalized using the instantaneous traffic normalization factor$\boldsymbol{A(t)}$. This is to make the traffic behaviour at each eNodeB of the propose model exhibits the temporal diversity of a typical cellular network. The load factor of jth eNodeB after normalization is given as [21]:

$$\rho_{j,new'}(t) = \boldsymbol{A(t)}\rho_j(t) \qquad (10)$$

Where: $\rho_{j,new'}(t)$ is the normalized instantaneous load factor of the jth eNodeB at time t; $A(t)$ is the instantaneous traffic normalization factor and $\rho_j(t)$is the calculated load factor of the jtheNodeB at time t.
Thus, the instantaneous power consumed by the LTE access network of NeNodeBs at time t is given as [21]:

$$P_N(t) = \sum_{j=1}^{N} [(1-q)\rho_{j,new'}(t) P_j^a + q P_j^a] \qquad (11)$$

The total energy consumed by the N eNodeBs over a period of 24 hours can be computed using equation (12) and is termed as the original/base-case energyE_N^{orig} which is given as [21]:

$$E_N^{orig} = \sum_{t=0}^{24} P_N(t) \qquad (12)$$

In the proposed model, active mobile stations are selected randomly from a set of uniformly distributed mobile stations. Each mobile station is defined by its X and Y coordinates. Mobility is simulated by randomly selecting a set $(u_{x,i}, u_{y,i})$ of positions within a particular cell. Mobile stations are initially generated uniformly across the entire network. A set of active mobile stations is selected from the group of N_u uniformly distributed mobile stations belonging to each cell. Let D be the distribution factor of the mobile stations in each cell, the number of mobile stations that are located within every cell for a given value of D is expressed using [21]:

$$N_u = 6D^2 + 8D + 3 \qquad (13)$$

Energy saving is achieved when active eNodeBs dynamically transfer their loads/traffic to their adjacent cells in other to switch to sleep or off mode depending on the status of the adjacent eNodeBs. This load/traffic sharing results in an instantaneous increase in power consumed by the adjacent eNodeBs due to the increase of its transmission power to extend it coverage area to the off or sleep eNodeB. This increase in the instantaneous power of the $j\ th$ eNodeB to cover the coverage area of an off or sleep mode adjacent eNodeBs can be computed using [22]:

$$P_{INC,j} = \frac{m(t)P_{TX,j}}{6} \qquad (14)$$

Where:
$m(t)$is the number of off or sleep mode adjacent eNodeB whose load is been transfer to the $j\ th$ eNodeB at time t.
The total energy consumed by N eNodeBs over a period of 24 hours with the energy saving algorithm is termed as the energy-with-scheduling E_N^{wshc} and its expressed using:

$$E_N^{wshc} = \sum_{t=0}^{24}\left[\sum_{j=1}^{N}[S_j(t)\,((1-q)\rho_{j,new}^{+}P_j^{a+} + qP_j^{a+}) + (\left(1-S_j(t)\right)P_j^{s})]\right] \qquad (15)$$

Where:
$S_j(t)$is the operating mode indicator of the $j\ th$ eNodeB at time t and it is given as:

$$S_j(t) = \begin{cases} 1\ active\ mode \\ 0\ sleep\ mode \end{cases} \qquad (16)$$

$\rho_{j,new}^{+}$is the new normalized load factor of the jth eNodeB after implementing dynamic scheduling at time t.
$P_j^{a+}$is the new operating power of the jth eNodeB after coverage extension and it is expressed using [22]:

$$P_j^{a+} = a\left(P_{TX,j} + P_{INC,j}\right) + b \qquad (17)$$

Thus, the proposed net energy savings in the network is expressed using:

$$E_S = \left(\frac{E_N^{orig} - E_N^{wshc}}{E_N^{orig}}\right) \times 100\% \qquad (18)$$

Where:
N is the number of eNodeBs in the LTE access network,
$E_N^{orig}$is the base-case energyconsumption of the NeNodeBs
$E_N^{wshc}$is the energy consumption with scheduling of the NeNodeBs.

In order to maintain the quality of service offered to the mobile stations by the energy saving algorithm, certain number of resource blocks of the eNodeBs are usually left unused by the active mobile stations. This is done in order to prevent over-loading resulting from traffic with fluctuating bit-rates and sudden rise in total traffic. The quality of service offered by the energy saving algorithm is measured by a metric called blocking probability which is used to specify the reserve resource blocks (margin) at each eNodeB. The blocking probability of a new call/mobile station at the jth eNodeB at time t is expressed using:

$$Pr_{b,j}(t) = \frac{\frac{\left(N_{rb}\rho_{j,max}(t)\right)^{N_{rb}}}{N_{rb}!}}{\sum_{k=1}^{N_{rb}}\frac{\left(N_{rb}\rho_{j,max}(t)\right)^{K}}{K!}} \qquad (19)$$

Where:
$\rho_{j,max}(t)$is the maximum allowable load utilization factor of the jth eNodeB at time t.

The quality of service constrain is imposed at each eNodeB while performing scheduling/load transfer. The quality of service constrain is represented using:

$$Pr_{b,j}(t) \le Pr_{b,max} \qquad (20)$$

Where:
$Pr_{b,max}$is the maximum allowable blocking probability.

A The Load/Traffic algorithm

This algorithm dynamically transfer/share traffic among eNodeBs in a given LTE cellular access network in order to achieve energy saving. In the proposed energy saving algorithm, the eNodeBs can either be in the following modes:

i. Active mode
ii. Sleep mode
iii. Off mode

Traffic sharing result in an increase in eNodeBs transmit power, while the eNodeBs that have successfully shared their entire load decreases their power consumption to a level either equal to P_{sleep}or P_{off}. The following set of instructions form the proposed load/traffic sharing algorithm.

i. Generate the neighbour matrix
ii. Replace each neighbour by its traffic and sort the neighbours in descending order of their traffic size/load factor.
iii. Determining the available space in each neighbour while imposing the safety margin constrain/blocking probability.
iv. For each of the eNodeB, attempt traffic sharing from the eNodeB with highest traffic to the eNodeB with the lowest traffic.
v. If traffic sharing is not possible for a particular eNodeB, go to the next eNodeB with the lower traffic and continue until the entire eNodeB are exhaust.
vi. For each successful sharing, increment the sharing counter.
vii. Determine the new load factor of each of the eNodeB after sharing process is completed
viii. Determine the number of sleeping and off eNodeBs
ix. Subtract the number of sleeping and off eNodeB to obtain the number of active eNodeBs.

B Energy Saving Algorithm

The energy estimation algorithm [18] and the load/traffic sharing algorithm are integrated to form the proposed dynamic energy saving algorithm. The following set of instructions are executed logically to achieve the proposed energy saving algorithm. The sequential steps involved are as follow:

i. Initializing the simulation parameter
ii. Estimate the energy consumed at time t using the energy estimation algorithm
iii. Extract the load factor of the eNodeBs from the energy estimation algorithm and feed it to the load/traffic sharing algorithm to generate a new load factor LF_{new}, number of sharing and number of sleeping and off base stations.
iv. Store the energy obtained from (ii) as the base case energy (E_N^{orig}).
v. Compute the new energy based on the parameters obtained from (iii) and store the energy as the energy with scheduling (E_N^{wshc}).
vi. Repeat step (i) to (v) as long as the timer reading is less than the common duration (24 hours) while adding up the energy saving.
vii. Compute the Energy savings

Simulation and Result

The performance of the proposed dynamic energy saving algorithm was evaluated by simulation. The simulated LTE access network consist of 50 macro cells with a distribution factor of 4 and 100 active mobile stations per eNodeB. The choice of 50 eNodeBs is based on the number of eNodeBs which was used in the energy saving algorithms for LTE access networks proposed by [16].The standard parameters used for the simulation are shown in Table.1 which are consisted with the simulation scenario recommended by 3GPP [23]:

TABLE 1: Standard Simulation Parameters

Parameter	Value
Transmit power of eNodeBs	$46\ dBm$
System bandwidth	$20\ MHz$
Carrier frequency	$2\ GHz$
Bandwidth per Resource	$180\ kHz$
Resource block per eNodeB	100

The radius of the macro cell is chosen as 1.5 km. Adaptive modulation and coding (AMC) set parameters are given as $\xi = 0.75$,$\gamma_{min} = -6.5\ dB$, $\gamma_{max} = 19\ dB$ and $e_{max} = 4.8\ bps/Hz$[23]. Five classes of real time constant data rate having data rates equal to 64 kbps, 128 kbps, 256 kbps, 384 kbps and 512 kbps are randomly selected by mobile stations. It is assumed that only one resource block can be allocated to a mobile station from any class. Thus, the required signal-to-noise-ratio of the five classes, calculated using equation (6) – (7), are found equal to $-4.1\ dB$, $-0.3\ dB$, $4.3\ dB$, $7.9\ dB$, and $11.1\ dB$ respectively. The eNodeBs power profile parameters are: $A = 21.45$ and $B = 354.44$ for macro cells. These parameters provide the maximum operating power of the eNodeBs [18]. The energy load proportionality constant q ranges from 0 to 1. A snap shot of the simulated network is as shown in Fig.2.

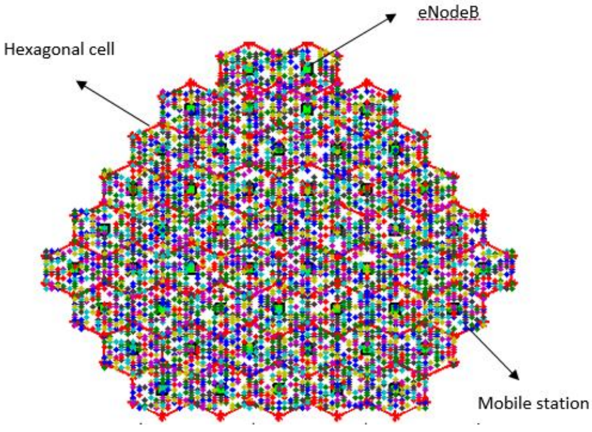

Fig.2. Simulated Network of 50eNodeBs

The daily energy saving resulted from integrating the load/transfer algorithm with the energy estimation algorithm to form the energy saving algorithm of the LTE access network was plotted against the energy load proportionality constants which ranges from 0 to 1 at an interval of 0.1 for the call blocking probability of $0.001\%, 0.01\%, 0.1\%, 1\%$ and 10%. The dependency of the energy saving on the energy-load proportionality constant for the various call blocking probability is as shown in Fig.3.

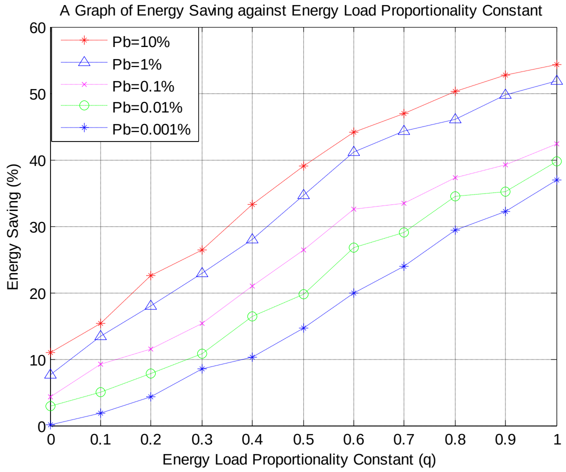

Fig.3. Energy Saving against Energy Load Proportionality Constant

The energy saving from Fig.3 is highest for the energy load proportionality constant of 1, which corresponds to constant energy-load proportionality constant. This is because for the constant energy load proportionality constant, the eNodeBs consume constant power irrespective of their traffic level which result to the highest amount of energy consumption of the LTE access network and consequently the highest amount of energy saving which correspond to$36.87\%, 39.67\%, 42.32\%, 51.84\%$ and 54.24% for the call blocking probability of $0.001\%, 0.01\%, 0.1\%, 1\%$ and 10% respectively. However, as the energy-load proportionality constant tends toward zero, the dependency of the energy consumption of the eNodeBs increases with its load utilization level, hence the energy consumption and energy saving decreases. Subsequently, for the energy load proportionality of zero, the energy consumption of the eNodeBs fully depends on its load utilization, and hence the energy saving is lowest and corresponds to 0.12%, 2.95%, 4.23%, 7.56% and 10.91% for the call blocking probability of 0.001%, 0.01%, 0.1%, 1% and 10% respectively.This is because the network incurs extra power (additional transmit power) in transferring the mobile stations from the off/sleep mode eNodeBs to the neighbouring active eNodeBs. Also, to further portrait the dependency of the energy saving on the call blocking probability for the various energy load proportionality constant range from 0 to 1 at an interval of 0.1, the energy saving of the network was also plotted against the call blocking probability ranging from 0 to 10 at an interval of 1, for the various energy load proportionality constant as shown in Fig.4.

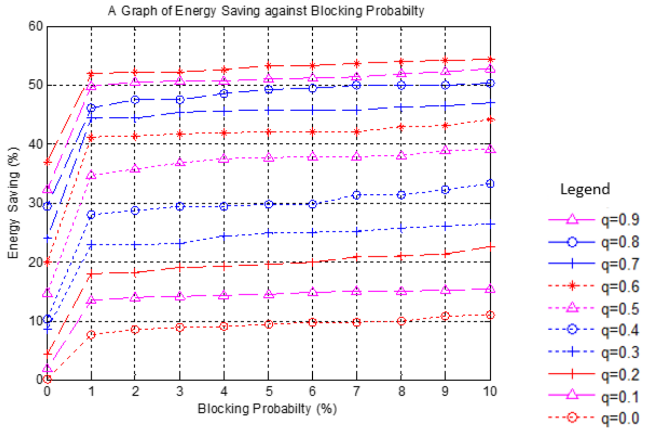

Fig.4. Energy Saving against Call Blocking Probability

Fig.4. depict the estimate of how much energy the network can save for a particular call blocking probability. The plot shows that the percentage energy saving of the network increases if the network allows higher call blocking in the network. This is because allowing higher call blocking means less eNodeBs are required to serve the active mobile stations, that is more eNodeBs are allowed to sleep/off by the energy saving algorithm and hence higher energy saving. Thus, for the call blocking probability of 10%, the energy saving is highest which corresponds to 54.24%, 52.77%, 50.21%, 46.87%, 44.16%, 39.05%, 33.28%, 26.40%, 22.50%, 15.34% and 10.91% for the energy-load proportionality of 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1 respectively. However, as the call blocking probability tends to zero, the energy saving in the network reduces gradually until a call blocking probability of 1% is reached, and there is a drastic reduction in the energy saving in the network for call blocking probability that is less than 1%. Thus, the optimum energy saving in the network was achieved while maintaining a call blocking probability of 1% which corresponds to 51.84%, 49.82%, 46.08%, 44.35%, 41.14%, 34.71%, 28.03%, 22.95%, 17.95%, 13.34% and 7.56% for the energy-load proportionality of 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1 respectively.

The proposed energy saving algorithm was validated by comparing its performance in terms of energy saving with the always on algorithm and the eco-inspired sleep-wake algorithm which was applied to save energy in LTE access network by [16] while using call blocking probability as the quality of service parameter. The energy saving of both the proposed energy saving algorithm and the eco-inspired sleep-wake are all reference to the energy consumption of the always-on algorithm which is the base-case energy consumption. The plot of the energy saving against the energy load proportionality constant of the proposed energy saving algorithm and the eco-inspired algorithm as applied to the LTE access network while guaranteeing a call blocking probability of 1% is as given in Fig.5.

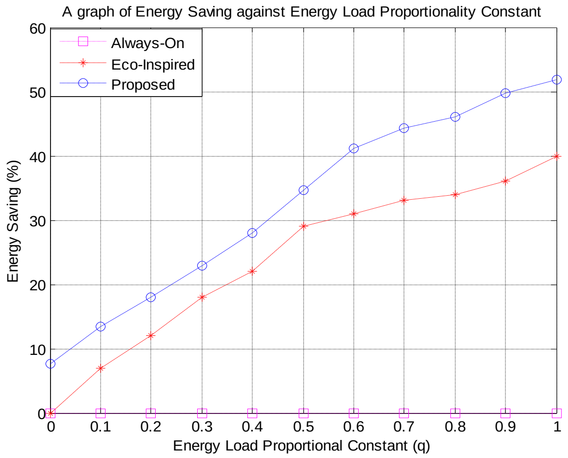

Fig.5: Comparison Energy saving of Proposed Algorithm and Existing Algorithms

Fig.5 shows a qualitative comparison of the proposed energy saving algorithm with the eco-inspired sleep-wake algorithm. Comparison is presented for the energy saving against the energy load proportionality constant while guaranteeing a call blocking probability of 1% . As can be seen in Fig.5, energy saving of the proposed dynamic energy saving algorithm is higher than the energy saving of the eco-inspired sleep-wake algorithm for the energy load proportionality constant ranging from zero to one. The energy saving of the eco-inspired sleep-wake algorithm and the proposed algorithm is highest for the energy load proportionality constant of 1 with values of 40% and 51.84% as reference to the always on algorithm respectively. This shows that the proposed dynamic energy saving algorithm achieved a highest energy saving of 51.84% and 11.84% with respect to the always on algorithm and eco-inspired sleep-wake algorithm respectively, while guaranteeing a call blocking probability of 1%

Conclusion

The dynamic algorithm for improving energy saving in LTE mobile networks through off mode, sleep mode and multi-cell cooperation utilization at the eNodeBs has being developed.

The LTE network environment and the eNodeBs power consumption models were developed with a view to implementing the dynamic energy saving algorithm which comprises of the energy estimation algorithm and the load/traffic sharing algorithm. The energy estimation algorithm estimate the energy consumption of the eNodeBs when they are powered on irrespective of their utilization. The load/traffic sharing algorithm transfer traffic between eNodeBs which enables the off mode, sleep mode and multi-cell cooperation of eNodeBs. The dynamic energy saving algorithm algorithm was implemented on MATLAB 2013b environment. The simulation of the energy saving resulted from the energy saving algorithm was done using the developed MATLAB graphical user interface called the LTE network energy saving analysis software based on dynamic scheduling for the energy load proportionality constant ranging from $0$to 1. The results shows that the energy saving in the network increases as the energy load proportionality constant and call blocking probability increases. This shows that the proposed energy saving algorithm achieved the highest energy saving of 51.84% and 11.84% when the energy load proportionality constant equals 1 with respect to the always-on algorithm and eco-inspired sleep-wake algorithm respectively, while guaranteeing a call blocking probability of 1% . This work only focus on downlink communication (that is from eNodeB to mobile stations). Nevertheless, it would be interesting to develop a dynamic energy saving algorithm for eNodeBs that considers downlink and uplink traffics jointly.

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