A Novel Approach for Energy-Aware Base Stations Operation in Green Cellular Networks

C. Carin Sharon, N. Nirmal Singh, S.Thilagavathi

Abstract—The massive improvement in the wireless market and cumulative traffic demand urged the network providers to choose new techniques like dense deployment of base station (BSs) to provide extensive data rate services with minimal operating expenditures at low energy requirements. These challenges encouraged towards the design of energy conservative BS snoozing and corresponding user association throughout the low traffic period with load balancing for guaranteed service quality for green cellular network operation. For the duration of little traffic, the related BSs can enter into sleep mode after handovering its users to its nearby BSs, saving energy thereby. Message passing with Load balancing algorithm (MPLA) is proposed, which exchange messages around BSs on a distributive way and also it permits those BSs to finish up with extreme choice ahead if it ought to stay active or idle to reduce energy wastage. The burden is increased by the handover process in its neighboring BSs which can substantially decrease the data rate, hence the load balancing is performed. Simulation results using MATLAB reveals that MPLA significantly reduce the energy wastage and enhances the ongoing service quality to users.

Index Terms— Base station sleep mode, Energy effective operation, Green cellular networking, Load adjusting, MPL Algorithm.

1 Introduction

THE remarkable improvement in the network technology made the base transceiver station a massive energy consuming device [15]. The uninterrupted operation of BSs with varying high spatial and temporal traffic makes the BSs to be exploited inefficiently for large part of day and ends up in an unproductive energy usage [5]. The increasing traffic demand created a significant effect on the environment by emitting colossal amount of CO2 thus intensifying the greenhouse effect [4].

The improvement in cellular infrastructures escalates the energy utilization which includes an immeasurable influence on carbon emissions [2]. Fig.1 delineates that BSs are the vital energy consuming hardware, devouring a total of 65% to 85% energy, the portable unit (MU) devours just 15% to 20% energy while other devices consumes below 10% of energy [7],[11]. The growing energy expenditures and environmental alarms insisted the network providers to move towards green mobile network [6]. The motivation is to reduce the BS energy consumption by BS sleep procedure.

A few methodologies has been put forward to acknowledge energy effective base station operation from equipment outline (e.g., Power amplifier design and natural techniques for cooling) to topological methodologies (e.g., relays, small cells and so on.) [16]. Dynamic load-aware BS sleep operation as in [13] permit the BSs to be totally idle all through the little rush hours [8] and possibly cut the energy wastage yet it don't guarantee quality of service.

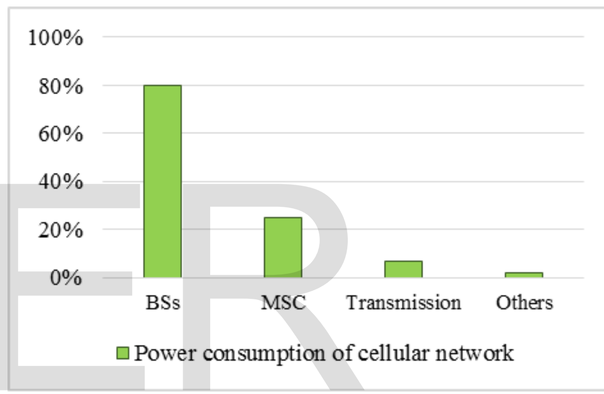

Fig. 1. Power consumption of a cellular network.

Depending upon the traffic conditions, resizing the cells by either extending or contracting the cell size [10] can most likely adjust the movement load and decrease the energy wastage. But it has restrictions in the interference between adjacent cells and poor coverage. To face the increasing traffic demand with high data access, densification of network with small cells increase the service quality to users [14]. Conversely small cell demand enormous quantity of spectrum, that could be a scares resource.

The BSs working with little activity are chosen and its users are handovered to adjacent BSs by transferring messages among the BSs [1], [12] and permitting the BS to go into an idle state thereby the energy wastage is limited. The BS sleep operation with load adjusting procedure can be completed through five levels:

1. User assignment
2. Transfer of messages between BSs
3. End user Transfer
4. Managing the load
5. Energy productive system operation

The different parameters which is utilized for the execution

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of algorithm are considered from [1] are delineated in TABLE 1

TABLE 1
SUMMARY OF PARAMETERS

Symbol	Quantity
N	No. of Base stations.
K	No. of active Base stations.
U	No. of Users.
i	Index of base stations, $i \in \{1, 2, 3, \ldots, N\}$.
a	Index of Users, $a \in \{1, 2, 3, \ldots, U\}$.
u_i	No. of active users.
$F_i(u_i)$	Function representing the power required by BS 'i' serve its users 'u_i'.
P_i	Transmission power required by BS to serve its user
y_i	No. of active BSs among ith BSs.
ς_i	Preference for BS 'i' in BS link.
γ_i	Whether BS 'i' is active.
ψ_i	Forward message.
δ_i	Backward message.
C	Channel capacity.
B	Bandwidth.
P_L	Path loss.

The rest of the paper is organized as follows: Section 2 portrays the framework model and algorithm usage. In section 3, we confer simulation results. Finally, we conclude the paper in Section 4.

2 System Description

2.1 System Model

A cluster involving 'N' BSs and 'U' users are considered. All BSs expend similar energy and every users displays similar traffic burdens. Fig. 2 demonstrates a cluster with 2 BSs and 3 users. The active users constitute the total traffic. By proper traffic estimation, the BSs that has to remain active to provide service to the users are identified. The circle symbolizes the continuing state of BS, white color representing dynamic state and grey color representing the idle state. The sturdy line signify the strong signal strength between BS an its users while the dotted lines representing week connectivity. Dark lines between BS symbolize the linkage among BSs. The function representing the energy required by BS 'i' serve its users 'U_i', $F_i(u_i)$ [1] is obtained by (1):

$$F_i(u_i) = -P_i \mathbb{I}(u_i > 0) - 14(u_i + 1)\log(u_i + 1) \quad (1)$$

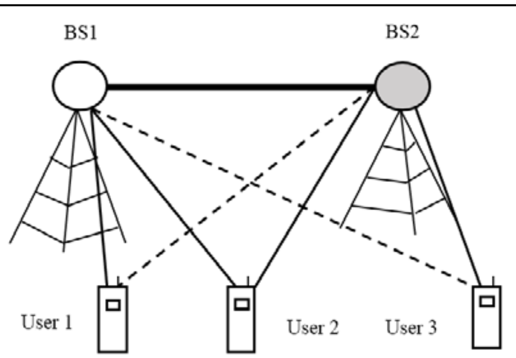

Fig. 2. System model.

2.2 Message Passing with Load Balancing Algorithm

Fig. 3 gives the methodology for Message Passing with Load balancing algorithm.

The MPL algorithm, trade messages among BSs until the messages converges to an ideal value and ends with the choice on which BSs ought to stay dynamic and which needs to stay as an idle to save energy. The general message upgrade rules [1] for an iteration is given by (2) and (3):

$$\varsigma_i^{(t)} = \max[\delta_i^{(t)}(y+1) + \psi_{(i-1)}^{(t)}(y)] - \max[\delta_i^{(t)}(y) + \psi_{(i-1)}^{(t)}(y)] \quad (2)$$

$$\gamma_i^{(t+1)} = F_i^t(0) - F_i(0) \quad (3)$$

After the handover of users to adjacent BSs, load balancing [3] is done depending upon the need. For load balancing, channel capacity and Cost 231 Hata model of path loss are calculated by (4) and (5):

$$C = B\,log_2(1 + SNR) \quad (4)$$

$$P_L = 46.3 + 33.9\log_{10}(f_c) - 13.82\log_{10}(h_b) - a(h_m) + (44.9 - 6.55\log_{10}(h_b))\log_{10} d \quad (5)$$

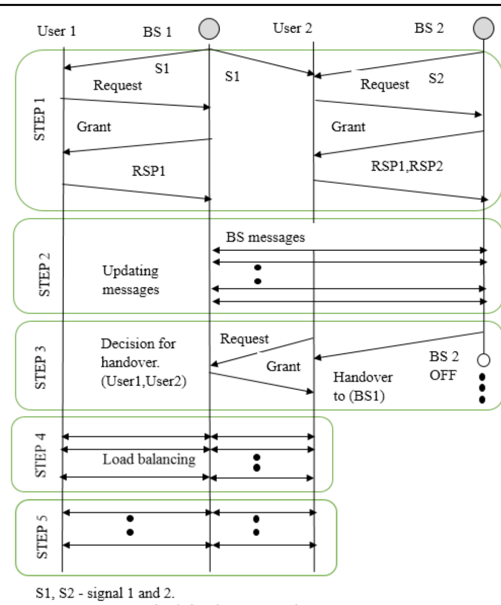

Fig. 3. Flow diagram for MPLA.

MPL algorithm

To begin with: *Set BS-User message =0.*

repeat

At user: *At user 'a', update User-BS message and send it back to BS 'i'.*

At BS: *BS 'i' update BS-User message and resend it to user 'a'.*

iterate: *Run forward-backward message updates among all BSs and find updated BS-User message using (2) and (3),*

until *maximum iteration is reached,*

Choice: *Determine their states and user associations for all BSs.*

for each Users: *Find the total power for establishing the link with BS using (1).*

iterate: *compute channel capacity and Path loss using (4) and (5).*

While

User larger than threshold value after handover, perform load balancing [3] and calculate total channel capacity.

To finish: *Allocate data rate for all users.*

end

3 Simulation And Discussion

We test the MPL algorithm using MATLAB [9]. For the simulation model, we consider a cluster of cells where all BSs (*N*=20) and users (*U* =150) are arbitrarily situated inside a 1 km x 1 km square region [1] and the number of dynamic BSs is set to *K*=15 and 10 as portrayed in Fig. 4. The messages are real numbered variables which contains data about the dynamic users in each BSs, accessible resources, adjacent BSs, traffic in each BSs. Fig. 5 delineates the necessity of BSs (for *K*=10 and *K*=15 individually) to be dynamic regarding the users (*U*=150).

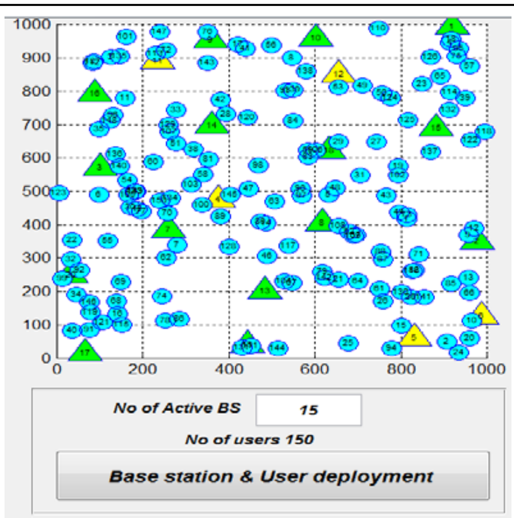

Fig. 4. BSs-User deployment for K=15. Green and yellow triangle denotes the active and idle BSs respectively. Circles represent the active users.

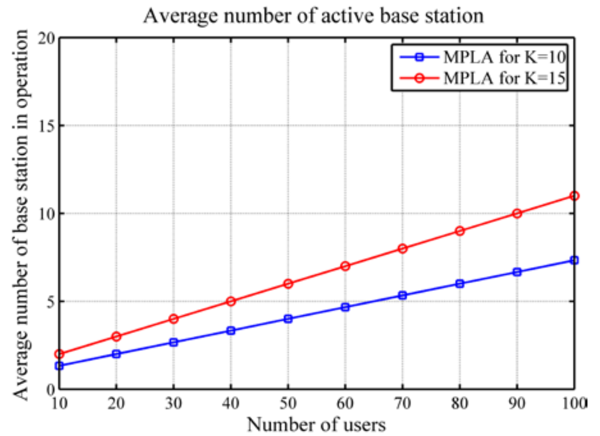

Fig. 5. Active BSs (when K = 10 and 15) Vs. Users.

With lesser users, just few BSs stay dynamic. At the point when *K* = 15, for user *U* = 20, just 3 BSs stay dynamic while it increments to 8 dynamic BSs for *U* = 60 and increments to 11 dynamic BSs when *U*=100. At the point when *K* = 10, for user *U* = 20 is just 2 BSs stay dynamic while it increments to 4 dynamic BSs for *U* = 50 and increments to 7 dynamic BSs when *U*=90. The BSs requirement increases with increasing number of users. Fig. 6 demonstrates the energy need by BSs (for *K*=10 and *K*=15 individually) to serve the users.

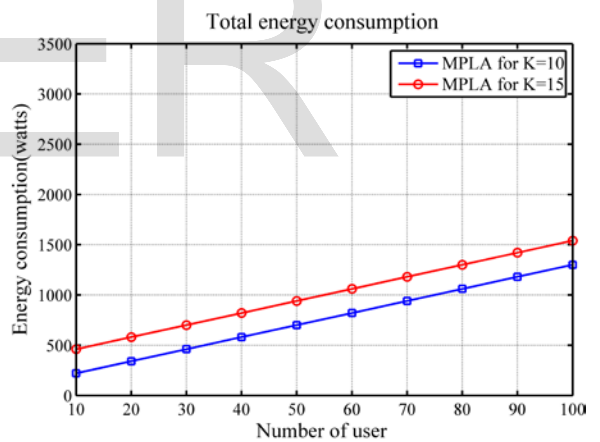

Fig. 6. Energy requirement by BS (K = 10 and 15) Vs. Users.

Whenever *K*=15, for 10 users, the energy utilization by 3 BSs are 600 watt while this increments to 1000 watt for 8 dynamic BSs to serve 60 users and further increments to 1500 watt for 11 dynamic BSs to serve 100 users. Additionally when *K*=10, for 20 users, the energy utilization by 2 BSs are 400 watt while this increments to 800 watt for 4 dynamic BSs to serve 50 users and further increments to 1200 watt for 7 dynamic BSs to serve 90 users. With a lesser users, just few BSs stay dynamic. When the number of users increases, more BSs are set to dynamic which increment the energy requirement. In general, energy necessity rises when users increments. Fig. 7 portrays the energy saving by dynamic BSs (*K*=10 and *K*=15 separately).
Whenever *K*=15, for 10 users the energy savings is 49% which reduces to 33% for 50 users and further decreases to 10% for

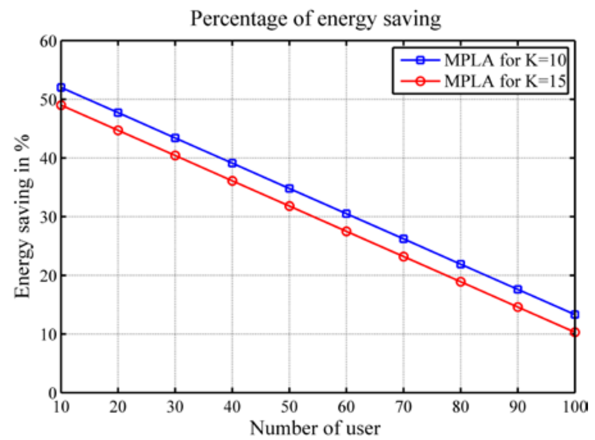

Fig. 7. Percentage of energy saving Vs. Users for 10 and 15 active BSs.

100 users. Likewise when K=10, for 10 users the energy savings is 50% which reduces to 35% for 50 users and further decreases to 12% for 100 users. Fig. 8 demonstrates the information rate for users after and before load balancing.

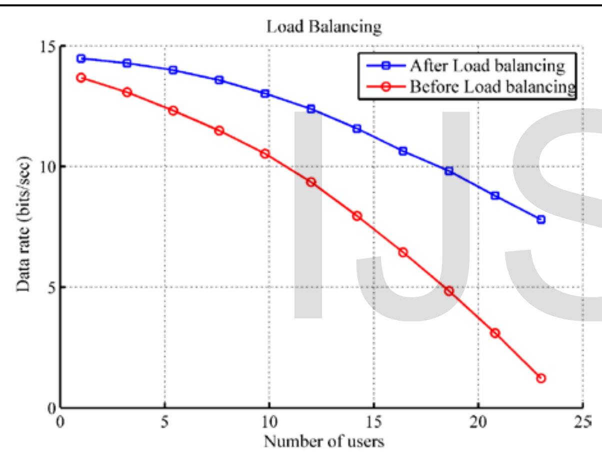

Fig. 8. No. of users Vs. data rate for after and before Load balancing.

The MPLA decreases the aggregate energy requirement of the system to 50% by adaptively turning off BSs and reconfiguring the associated users to neighboring BSs. Load balancing [3] is done after a certain threshold value is reached. After handover, the load of its near-by cells expands which can reduce the information rate to the users. Before Load balancing, for 24 users the information rate is 2 bps and after Load balancing the information rate increments to 7 bps. Load balancing guarantees minimum information rate for all users.

4 Conclusion

The under-used BSs are distinguished from the other and choices with respect to the condition of BSs whether to make the BS to end up with the decision either to be idle or to stay dynamic is done by MPL algorithm for reducing the energy wastage. Load balancing is performed to distribute the information rate similarly to all users for requisite QoS. With BSs sleeping and load balancing, an aggregate energy saving of 50% with ensured QoS is achieved.

To meet the increasing traffic demands, future work can be perused in heterogeneous cellular network. With the analysis of the traffic pattern, the energy saving can be done by both BSs sleeping and cell resizing. During the peak traffic hours, to save energy, cell resizing can be done by adjusting the transmission power of microcell BSs and during low traffic periods, the underutilized microcell BSs are identified and are made idle to save energy.

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