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# Reduction in Energy Loss Using Automatic Base Station Switching Operation in Cellular Network

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**Abstract:** The cellular network is a network where a large coverage area is divided into smaller areas called cells, handled by less powerful base station, that use less power for transmission. The cellular network prevents frequency spectrum congestion, so the available frequency spectrum can be reused from one cell to another. To minimize the energy loss, a Reinforcement Learning (RL) framework was introduced. RL framework comprises of Markov decision process (MDP) and transfer actor-critic-learning framework (TACT). In MDP, the estimation of traffic load is performed by base station controller (BSC). Speed of the learning framework can be upgraded by TACT. Both the techniques can take decision regarding turning ON/OFF base stations. In this paper, we have proposed modification in the RL algorithm ensuring that the number of users and traffic load are estimated and pass down to the BSC. The base station switching operation is carried out automatically by the BSC. Fixed nodes and Mobile nodes are introduced in the base station range, thereby, improving energy consumption and the resulting process will be accurate.

**Key words:** Base stations(BS) · Reinforcement learning(RL) · Transfer actor-critic algorithm(TACT) · Markov decision process(MDP) · Base station controller(BSC) · Traffic load analyzer · Fixed nodes · Mobile nodes

## INTRODUCTION

In our day-to-day used communication system, the network is subdivided into five categories- Local area network (LAN), Wide area network (WAN) and Metropolitan area network (MAN), wireless network, internetwork. Wireless network is the fastest growing segment in our communication scenario through which information transmission and network connectivity to other devices and internet can be accessed without any wire connections or cables. Overall telecommunication operating system becomes easier. Wireless network is of two types- infrastructure and infrastructure less network. In infrastructure mode, one device communicates with the other by passing through an access points (AP) which is commonly called base station (BS). Whereas in infrastructure less mode, devices present in wireless network communicate directly without the requirement of a centralized access point (AP). In cellular network, each individual cell is allocated with different set of frequencies compared to its neighbouring cells which avoids frequency interference. Transmission of data from one base station to another should take place without any loss. Due to the smaller sizes of the cell, the transmission of data takes place without the occurrence of loss; hence, the energy consumption is less in cellular network.

The reinforcement learning algorithm comprises of Markov decision process (MDP) and transfer actor-critic-learning framework [1-3]. The MDP forecasts the traffic load variations in the future. It consists of parameters such as S, A, P where S denotes state space, A denotes action, P denotes probability function. Here state means state of the BTS, action means Traffic load increases per time. Based on these details it will control decision maker.

In the actor-critic-learning algorithm, at a given state (S), the actor (A) selects an action and executes it. This execution transforms the state of the environment to a new one and appoints costs to every action with certain probability (P). Then the critic criticizes the action of the actor and then updates the value function through a time difference (TD) error [4]. The model can be summarized into the following algorithm,

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*Step 1*: First let us select an action a (k) in state s (k).

*Step 2*: The users (or active nodes) in a particular location

'x' is connected and then starts data transmission.

*Step 3*: Based on this, cost function 'C' is estimated.

*Step 4*: Then identify the traffic loads and accordingly

Update the state and compute the TD error.

*Step 5*: Update the state-value function on by TD error.

*Step 6*: Update policy and select the action with low cost.

RL algorithm has TACT module that is used to speed up the energy consumption process [5]. BS coverage area comprises active and inactive node which consumes more amount of energy. But the process still takes time to determine the output of the energy consumption scheme. So a new scheme is proposed to determine the energy consumption of the base station. To make the TACT process faster energy availability scheme is proposed. In the proposed model, RL algorithm is modified. RL algorithm consists of MDP and TACT module. The two modules are performed to obtain the following parameters. The MDP consist of the number of active users (or active nodes), traffic load analyzer and signal strength analyzer [6]. Active user refers to the user who is currently consuming signal and bandwidth. Traffic load is the amount of data rate consumed by the users [7]. Signal strength analyzer checks the fading affect. All these parameters are given to the base station switching controller (BSC). BSC will decide the switching operation of micro and macro base station automatically.

Here, fixed nodes are used which do not changes its location from one BS coverage area to another. And the second node is the mobile node which changes its position from one region to another. The switching operation which will be carried out without knowing the number of active and inactive nodes will consumes more amount of energy. Whereas here base station will be aware of number of active fixed node. According to the number of active fixed nodes BSC will turn on the BS and thus consumes less energy. As only active nodes will be considered, less number of base stations will be turned on, therefore, less amount of energy will be consumed and time delay will be less. Also energy consumption will be lesser, so less greenhouse gas will be released. The pros of the proposed work are that present paper can have a better energy availability value and accurate process.

The proposed work presents an energy available scheme by using the automatic base station switching operation. It shows the energy consumption by the fixed and mobile active nodes and based on it shows an output which contains energy available in the BS. Basically, the scheme introduced will check the number of active fixed nodes present in the base station coverage area; the fading effect will be checked by signal strength analyzer that will reduce disturbance while transmitting the data; traffic load consumed by the nodes/users. Suppose, if the traffic present in an area can be handled by macro BS then all macro BS will be turned on. If the current traffic can be handled by micro BS then all micro BS will be turned on. If the current traffic needs both the base station then both of them will be turned on. Most of the time, micro base station should be used as it consumes less amount of energy. In the proposed model, while performing the simulation process, a single macro BS is converted into micro BS as all the micro station will be able to handle the traffic. So based on the current traffic, base stations are automatically switched on/off to have lower consumption of energy. If in an area, at a time, some BS are turned on due to the traffic present but after a few hours traffic will be decreased, in that case automatic switching operation of BS is required [8].

Automatic switching operation doesn't take much time and consumes less energy wherever traffic load is low. Energy availability scheme is introduced to control those areas which don't have heavy traffic all the time in a day. Only for a few hours traffic will be high and all other time it will be low so less number of base station will be required. By using automatic base station switching operation, active fixed nodes, traffic load of the users and noise in the transmission medium present in the coverage area of the base station can be determined by this scheme [9].

**Related Work:** Some reference papers are elaborated below by the help of which a faster energy availability scheme has been introduced.

The improvement in energy efficiency in Random access network can be achieved by dynamically switching on/off some base stations. Rongpeng Li *et al.* [8] has extended their research work introducing reinforcement learning (RL) framework. Previously base station switching operation was fully determined by the traffic load variations which cannot be pre-determined leading to time delay, energy loss and also affects costs. The overall switching operation is foresighted in the Markov decision process such that decisions regarding switching operation from one base station to another as demanded per time (traffic load varies with time) are performed fast. Switching operation is done by base station controller (BSC) based on the estimations of the traffic load by the MDP.

Reference [9] is particularly related with the Random access network (RAN) which involves multiple base stations (BSs) where traffic load (number of users) is constantly fluctuating which is very difficult to predict. The model underwent various simulations to improve energy feasibility. The massive popularity of portable devices like mobile phones in recent times has increased greenhouse gas emission. Huge traffic load which consumes huge amount of energy leads to huge emission of greenhouse gases. Transmission of data from one BS to another (turning on/off of base stations) will affect the base station with which the mobile terminal is connected, thereby, affecting other BSs of the coverage area leading to loss of energy. Simulations done had used costs and time difference (TD) error as parameters through which time delay in the overall switching operation and energy consumption is evaluated.

In [10], M. Marsan *et al*. has proposed reduction in the number of active cells in order to reduce the energy consumption. Active cells are the cells which are currently in active mode and are consuming energy. Since traffic load varies with time, these active cells can be switched off when they are not necessary because traffic is low. Even when some cells are switched off, it is ensured that the overall radio coverage, network connectivity, data transmission is performed by the cells that are active. This I s helpful in metropolitan areas where coverage area is divided into cells, it is seen that during day times all cells are active due to huge traffic but during night hours with the significant decrease in population most of the cells can be switched off and the coverage area can be covered by few active cells. Energy saving up to (25-30) % is possible. The method proposed here follows daily traffic pattern in a cell.

E. Oh *et al*. [11,12] has proposed that the energy consumption can be reduced by dynamic switching of BS with respect to the time varying characteristics of the traffic load of a coverage area. Traffic profile variance w.r.t the time shows that during day time traffic load is in peak level but during night hours traffic profile is low. In this paper, energy saving is done considering the mean, variance of traffic load and BS density. It provides guidelines on how to use BS resources and save energy. More research work can be done as more base stations are required in heterogeneous traffic.

Another related paper is [13]; the solution to the energy consumption problem is concentrated by two methods-user association and base station operation. For energy efficient user association, optimal energy efficient user association policy algorithm is used. For energy efficient base station operation, greedy-on and greedy-off algorithms are used. Energy saving upto (70-80) % is possible with this base station operation algorithm which primarily depends on the parameters arrival rate traffic load, BS density while deployment and spatial distribution of this access points. Using this algorithms, there is a huge energy savings in metropolitan/urban areas and very low or almost no energy savings is possible in rural areas as it maintains very low traffic profile. This is not reliable all the time and most of the decisions made are based on predictions.

**System Model:** In our model, a new scheme is proposed to modify the RL algorithm. The Energy availability scheme introduced consists of automatic base station switching operation and determines active fixed nodes and active mobile nodes present in the coverage area of a base station. While the handoff process (the transmission of an ongoing call or data from one base station to another base station coverage area.) takes place, BS will consume energy based on the number of users/nodes present in its range and traffic load and noise present in the transmission medium. In a BS range, initially, whether the nodes are active or inactive is determined. On the basis of active nodes, BS's will turn on. So, number of active users and traffic load is given to the BSC. Also, signal strength analyzer which controls the disturbance while transferring the data is given to the BSC. Based on these parameters, BSC will carry out the automatic base station switching operation.

The need of energy consumption scheme is important. For example, at a certain time in an area, number of active nodes and traffic load can be high so more number of BS's will be turned on; hence more energy will be consumed. After sometime the same area may not have

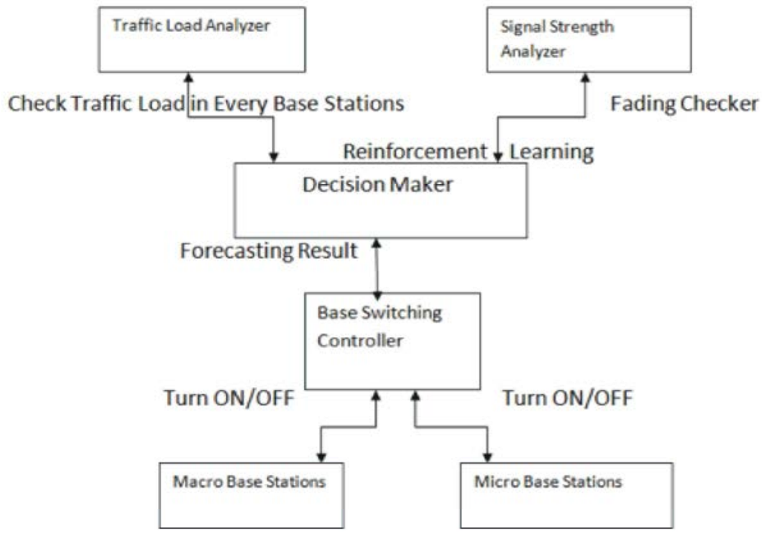


Fig. 1: Block for Energy availability scheme

that much active nodes and traffic load but still same number of BS will be turned on, therefore energy will be wasted. To save energy, it is necessary to know the number of active and inactive nodes present in the BS range. Energy available by transmission of data session through a channel can be used for transmission of other data session.

Here, a few numbers of active fixed nodes is considered in each base station coverage area and energy availability of each base station is checked. Fixed nodes don't moves from its own location to another location and remains in its base station coverage area, so energy consumed by the base station can be obtained. The parameters are given to the base station controller and switching operation is carried out. The figure below shows the block diagram energy availability scheme.

MDP consists of traffic load analyzer and signal strength analyzer. The requirement of traffic load analyzer is that it checks the number of active nodes and data rate consumed by them for transferring the data from one channel to another [14]. It is very necessary to know the active nodes present in an area. It is because some areas may be overloaded with active nodes during the morning time but during night, number of active nodes can be reduced. In that case, if the entire BS's which were turned on to control the morning traffic load will remain in ON mode till evening, energy will be wasted. Secondly, the BS will lose their energy and cannot provide it for further users which will make the transmission process slow. Signal strength analyzer is used to determine the noise present during the transmission of data. The signal strength analyzer works better if the distance between two users/nodes is less. If the distance is less, less noise will occur and signal strength can be easily determined but if the distance will be more, more noise will occur and thus signal strength will be weaker. Noise between the two users plays a significant role for data transmission as it may remove some data from the data packet and losses data packet path routed from source to destination and sometimes packet reaches late at the destination point [14].

All the parameters of MDP are given to the base switching controller (BSC). BSC needs human effort to determine the traffic load. The human needs to go and check the parameters of MDP on the screen which will cause time delay and resulting values i.e., how many BS's should be turned on might be incorrect. By using energy availability scheme, only active fixed nodes are considered by the BSC. Based on the number of active nodes, BS's are turned on/off. The BSC gives those values for base station switching operation.

To perform switching operation, an algorithm is followed. The algorithm considers the current traffic load of each node. The automatic base station switching operation will have better result and it will efficiently consume energy in BS during communication [15]. The nodes are controlled by different base stations.

The two base station used are:

- Macro base station.
- Micro base station.

Macro base station will cover maximum range of the network, so it will emit large amount of green house gases and it will consume high energy. Micro base station will cover minimum range of the network, so it will emit fewer amounts of green house gases and it will consume less energy. In this paper, to bring out the output i.e., energy available in the base station, some active nodes are considered. To cover all the active nodes, all the macro base station is turned on. But as macro BS consumes more amount of energy, the traffic load of the nodes will be checked. If it can be handled by the micro BS then all micro BS is turned on and a single macro BS is turned on. Again if the traffic loads changes then the single macro BS is turned into micro BS and all the micro BS handles the active nodes. Every time the traffic load is checked in the network and based on it macro/micro BS are turned on/off.

Mostly micro base station is preferred over macro base station as former consumes less amount of energy than the latter. The energy available in this scheme is compared with the energy consuming scheme where whether nodes are active or inactive are not known. Thus, energy available scheme shows that network which are aware of active nodes are left with more energy and therefore consumes less energy.

**Energy Availability Scheme in Reinforcement Learning Algorithm:** Finally, the model is summarized into the following algorithm for automatic base station switching operation.

Consider,
'T' denotes current traffic load.
'M' denotes macro base station and 'm' denotes micro Base station.
Min' denotes minimum traffic load and 'Max' denotes maximum traffic load.

*Step 1*: If T< Min, Turn On one Macro Base Station.
*Step 2*: If T> Max, check the traffic size.
*Step 3*: If m will control T, Turn On all micro station, otherwise check M and m availability based on T.

Macro and Micro base stations have their own capacity. The current traffic load is checked always and base on it macro and micro BS will be turned on/off. If minimum traffic load is less than current traffic load, macro BS will be switched on automatically. If current traffic load is more than maximum traffic load then micro BS capacity is checked. If all the micro stations can handle the current traffic load then all of them will be turned ON and no macro will be in ON mode. If micro BS cannot handle current traffic load alone then capacity of macro and micro BS will be checked. According to that BS will work and more energy will be available.

The energy consumed on different levels in the model is calculated which gives the average energy consumption. Energy can be consumed in four different states: switching, transmitting, turned off and idle. The energy consumption in each state is computed in time T. The first state is switching in which the decision is taken of turning on/off the base stations. The probability of being in switching state is $\pi 0$, can be given by Tsw/T. The second state is the transmitting state, here the data session is send from one active node to another. The probability of being in transmitting state is $\pi 1$ is given by average no. of bits per packet S to the average transmission rate R. Third is the turning off state in which inactive nodes are present. The probability of being in turning off state is $\pi 2$, given by Toff/T. Lastly, the idle state in which the base station remains completely in off mode. But still it will consume some amount of energy which should be calculated. The probability of being in idle state is $\pi 3$. It is given by Tidle/T. The average energy consumption for each state is Esw, Etx, Eoff, Eidle. Average power consumed is given by,

$$Eout = \pi 0\ Esw + \pi 1\ Etxr + \pi 2\ Eoff + \pi 3\ Eidle \text{ with } \Sigma\, \pi i = 1 \quad (1)$$

For the real time application of this scheme let's consider a Tech park which used to have lots of offices and so the number of active nodes will also be high during day time. Therefore, more number of BS's will be turned on which will consume more energy. But during night time when most of the offices will be closed and very less nodes will be in active mode, the whole BS's will be switched on which were on to handle the morning load, in this case energy gets wasted of the BS's. So, it is mandatory to know the presence of active and inactive nodes. In this paper, only active nodes are used and so less number of BS's are switched on. This will decide whether macro base station should be turned on or micro base station should be turned on. First, the current traffic load will be checked. If macro BS can handle the traffic nodes then it will be switched on and if micro BS can handle the traffic then it will be turned on. So, no human effort will be required and result will be accurate. Therefore, less energy will be consumed and hence more energy will be available.

**Performance Analysis:** We obtain energy availability of our proposed scheme by simulation. Here, we simulate seven base stations which consist of five active fixed nodes in each BS. The energy availability of the proposed scheme is compared with the model which is unaware of active and inactive nodes. It is obtained that the proposed scheme has more energy available than the previous scheme. The probability function given below shows the performance of the automatic base station switching operation.

$$P(T) = \begin{cases} 1, \text{ only macro is on} \\ 0, \text{ only micro is on} \\ \text{Otherwise, macro and micro are on} \end{cases}$$

As the algorithm is given, if the current traffic is less than minimum traffic load capacity then a single macro base station is turned on. For a single macro station "1" is assumed. Secondly, if the current traffic load is greater than maximum traffic load then all micro stations will be turned on which is denoted by "0". If the current traffic load can be handled neither by macro nor by micro base station then both of them will be turned on. If all the micro station can handle a traffic load then none of the macro station should be turned on. As a single macro base station may consume more amount of energy than all the micro stations. Micro base station consumes less energy and so more energy will be available. So, macro is less used than the micro base station in the heavy traffic load zone.

Table 1: Used Simulation Parameters

| Specifications | Values |
|---|---|
| Simulation area | 1Km×1Km |
| Number of base stations | 7 |
| Number of nodes in each base station | 5 |
| Maximum base station capacity | 150 |
| Minimum base station capacity | 100 |
| Current traffic load (T) taken | 60 (min), 175 (max) |
| Base station Height (h) | 30m (Macro BS) |
| | 10.5m (Micro BS) |

The graph shown above is the comparison between proposed energy availability scheme and existing energy consumption scheme. The graph is plot energy level Vs time. For the existing model, both active and inactive nodes are considered and for proposed model, only active nodes are considered. The energy available in the proposed is more i.e., approx 80 Joules whereas the existing method has approx 63 Joules. It is clear that the proposed scheme has higher energy availability than the existing scheme.

Mobile node changes its position from one BS region to another. So, it is necessary to update the location of the mobile node. The new BS will update its current location to its native BS. The expiry time will also be checked i.e., the time at which the MN left the previous BS. According to that only the new BS will provide signal to the MN for data transmission. There are chances to lose data while changing the BSs. So, the handoff process is done carefully. If the expiry time is not updated at correct time, then both the BSs will be in working mode.


Fig. 2: Performance graph for the proposed scheme using fixed node


Fig. 3: Performance graph of the Mobile Node

Thus, energy consumption will be high. The scheme introduced here provides better output for the mobile node.

From Fig. 3, the energy available in the existing scheme is 128J and in proposed scheme is 138J. Proposed scheme has 10J more energy available than the existing scheme which considers both active and inactive nodes.

## CONCLUSION

In this paper, we have modified the existing Reinforcement Learning algorithm. Only the active nodes are considered due to which less number of base stations will be switched on and thus consumed less energy. The base station switching operation will be done automatically. The automatic base station switching operation gives accurate result, therefore, reduced the time delay. The fixed active nodes are used which requires less number of base station to be turned on. Finally, a comparison is done between proposed scheme and existing scheme in which proposed scheme has more (approx 20%) energy availability.

The energy availability scheme in the proposed model can be used in those regions which are heavily crowded. Some areas will be busy for certain duration which, to control the traffic load during the busy duration, energy availability is used. It is used to reduce incorrect transmission from one user to another. If energy of all the base station will be saved and used for next nodes then data transmission will have higher transmission rate thereby reducing the time delay. For the future work, the energy available by using the fixed node and mobile node can be compared and get a better result.

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