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POWER CONSUMPTION OPTIMIZATION OF LTE-A NETWORK BY JOINT DEPLOYMENT OF RELAY STATION

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ABSTRACT

The growing number of users and macro base stations (BSs) in LTE-A network causes large amount of energy consumption for the whole network. In order to mitigate this problem, a sleep mode algorithm for Base Stations (BS) simultaneously powering Relay Stations (RS), deployed in the transmission area of selected BS considering the real time network traffic is proposed in this paper. The efficiency of power saving algorithms depends on an effective real-time network traffic detection and analysis. A method to detect and analyze real time mobile phone traffic in a cell is also proposed in this work. The number of Relay station to be deployed in the coverage area of a BS, transmission range and geographical areas to set up and factors for optimal deployment are also discussed in this paper considering the Qos parameter. Joint deployment of relay stations inter connected by X2 links and with the BS with the overlapped coverage is considered in this work. The deployment of relay station inter- connected by X2 links and with the Base station also meets the strategies for efficient group Handoff. The performance is analyzed by comparing power consumption of BS with and without the proposed algorithm, the simulation results shows there is good power saving with this proposed method.

Keywords: network traffic, joint deployment of RS, X2 link, control server, BS sleep modes, relay zooming, power consumption optimization, efficient handoff strategy.

INTRODUCTION

With the evolution of information and communication technology (ICT) and the rapid increase of massive data traffic, energy consumption by the network is also exponentially increasing. The deployment of 3G systems and now 4G technology in developing counties has significantly contributed for the development of information and communication systems of the nation but undesirably increased the power consumption of the network.

Several studies indicate that within telecommunication networks, the wireless access networks are high power consumers. Therefore, a lot of effort has been put lately in designing new power reducing techniques such as sleep modes and cell zooming. Sleep modes allow that a (part of the) BS can be switched off or put to power saving mode when there is no or little activity taking part in its coverage cell. Whenever necessary, the BS is waken up. When applying cell zooming, the cell size is adjusted adaptively according to the level of activity in a BS's cell. These techniques on their own can significantly reduce the power consumption in wireless access networks and combining them allows even higher power savings. In wireless systems the high energy consumption of a wireless base station (BS) results in non-economical, large value of electricity bill. Greater than 50% of the total energy in wireless network is consumed by the radio access part, whereas 50-80% is spent for the power amplifier (PA) [1]. In [2], it is also mentioned that the energy bill accounts the Operation Expenditure (OpEx) for around 32% in India and roughly 18% in the mature European market. Another important motivation for power optimization in wireless networks is environmental awareness. Many of the base stations (BS) in rural areas which are not connected to power grid are powered by diesel generators for complete day and night as well as backup power source for few hours per day in urban and suburban areas. These diesel generators consumes huge amount of Diesel and emits large quantity of CO_2, which is a GHG (Green House Gas), 3% [3] of the total CO_2 emission is from Information and communication technology (ICT) industry throughout the world by consuming 2%-6% [4]of the total worldwide energy. With the exponential growth of large data transfer, it is unblemished that the ICT sector will become a major CO_2 emission sources within the next few years. Large energy consumption combined with its adversative effects on climate and environmental changes results the need for an innovative energy-saving methods for future. In operators view the EE (energy efficiency) of wireless network not only bring ecological advantage and social benefits by solving issues for climate change but also has substantial economic benefits too[5].

Many international research projects like Green Radio [6], EARTH [7], [8], OPERANet [9], [10], and eWIN [11] which outlines the main solutions to energy efficiency in wireless communications are being carried out internationally.

The remaining Section of the paper is organized as follows. In Section 2 we described the methodology of our proposed work, with current scenario of network traffic profile and our proposed system model. In section 3 we presents a novel approach to find real time network traffic. Section 4 describes the factors for the optimal placement of relay station (RS). In section 5 we present our Relay Assisted BS Power Saving Algorithm (RABPS Algorithm). Significance of joint deployment of RS with BS for handoff management is defined in section 6. In section 7 we shows some relevant result to evaluate our proposed work and we conclude in section 8.

Methodology

The LTE-Advanced standard has specified the usage of relay nodes (RNs) as a cost efficient means to extend the capacity of a base station (termed eNB, evolved, NodeB) [12]. Each RS accesses the eNB through a wireless backhaul link (BL). It forwards data to and from some user equipment (UE) through a wireless access link (AL).

The network traffic is uncertain, but it is observed by practical studies and evident from various literatures that there is a periodic peak hour and off peak hours of network traffic daily and off peak hours during holidays and weekends [13]. Figure-1 [13] shows uncertain traffic pattern with peak and off peak hours. The implementation of sleep modes or power saving modes for BS requires an efficient estimation of online or real time mobile device traffic calculation or the number of MSs associated with the selected BS or RSs. This can be done by various existing methods such as calculating the current power load of the BS, prediction algorithms, and probabilistic analysis. Apart to these existing methods we have proposed a centralized algorithm to estimate the number of MSs associated to each RSs and the selected BS. Power consumption optimization in wireless access network is also a Green Technology which reduce Co2 emission from the diesel power generators installed at each BS during their sleep modes.

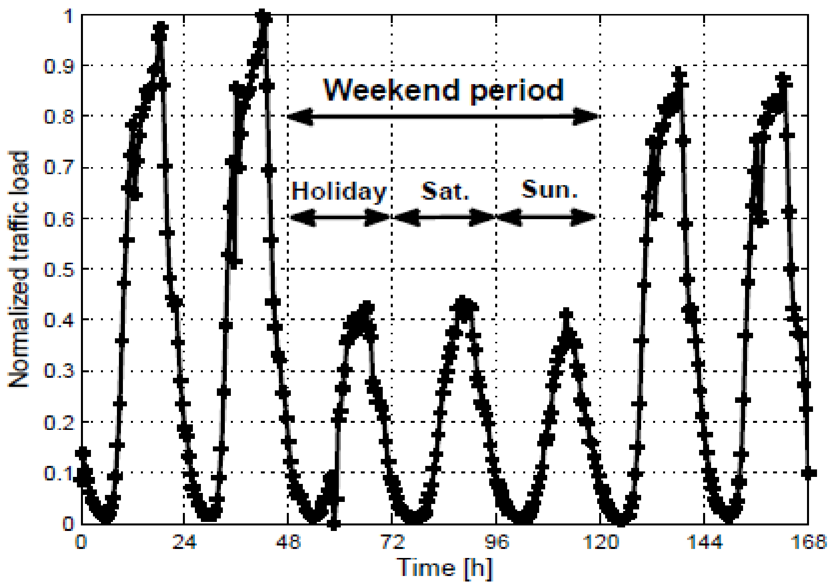

Figure-1. Uncertain traffic pattern of BS with peak and off peak hours.

System model

The BSs in the proposed work are evolved node B (eNB) which are capable of communicating with other BSs and RSs which are deployed inside the transmission area of selected BS through an X2 link [14]. The number of RSs to be deployed depends on the overlapping area of coverage for the selected BS. The control server (CS) placed at the BS collects the information of number of MSs associated to each relay station through X2 link and computes the algorithm to make RSs and BS to sleep mode. Figure-2 shows the proposed system model. The control server also takes part in handoff management process between the RSs deployed in the selected BS.

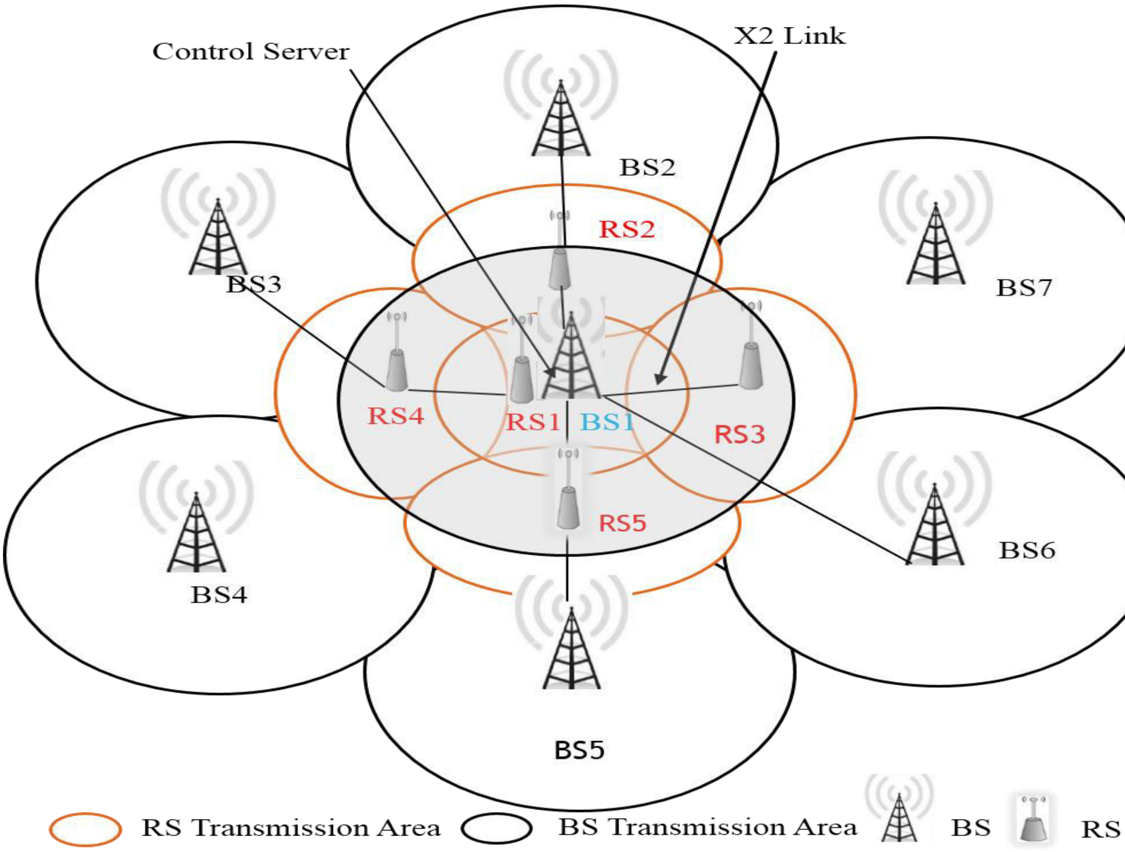

Figure-2. System model.

Real time network traffic estimation

The CS (cell Zooming server) installed at the BS site collects information about the all users (MSs) which are associated to the corresponding RS deployed in the transmission area "A" of selected BS through the X2 link. The process flow chart for relay station is described in flow chart shown in Figure-3.

The transmission channels of a RS are assumed similar to the BS as follows [15].

- Packet Control Channel (PCCH): The broadcast downlink channel that all phones listen to.
- Random Access Channel (RACH): The broadcast channel to mobile stations registered on the network.
- Standalone Dedicated Control Channel (SDCCH): A specific uplink channel assigned by the BTS or BS.

Each relay station broadcast a request message on its transmission area using PCCH to get back the number of user association. On receiving this message each MS send a replay containing details about the associated RS, signal strength and details of neighboring RS and its signal strength. If two or more channels are available, the MS will be associated to a channel which have good signal strength, even though the channels are associated to two different RSs irrespective of the distance between them. The data communication channel between RS and MS can be established similar to Standalone Dedicated Control Channel (SDCCH), a specific uplink channel assigned by the BTS.

The relay stations after collecting the data's of number of mobile stations (MSs) associated to it, will send this information to the Control server (CS) which is placed at the BS through the X2 link. The Control server (CS) compute an iXi matrix which is shown in Figure 4, with this collected data's, where i = number of RSs deployed within the transmission area of selected base station BSi. If for example there are five relays (RS1, RS2, RS3, RS4 and RS5) deployed in the transmission area of selected base station BSi, assuming these five relays collectively covers the total coverage area "A" of the selected base station BSi. Each diagonal elements of iXi matrix is the count of mobile stations associated alone to each relays RS1, RS2, RS3, RS4 and RS5.

A mobile station MS will be associated to only one relay at a time but from the data's we received (refer Figure-3) form each MS we can find the next nearby RS also with respect to the signal strength. This information is used to fill remaining fields of the iXi matrix which will be helpful to provide service to particular MS while predicting mobility and handoff. Total number of mobile station "M" in the area "A" of BS i is equal to sum of diagonal elements. If the total number of active MSs calculated is below a threshold value "T" of the total capacity of selected BSi, then the centralized algorithm to make BS to sleep mode can be computed. Now if any one

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diagonal element is "0" which means that there is no MSs associated to that particular RS so for further power consumption optimization this relay station RS can be put in to power saving/sleep mode.

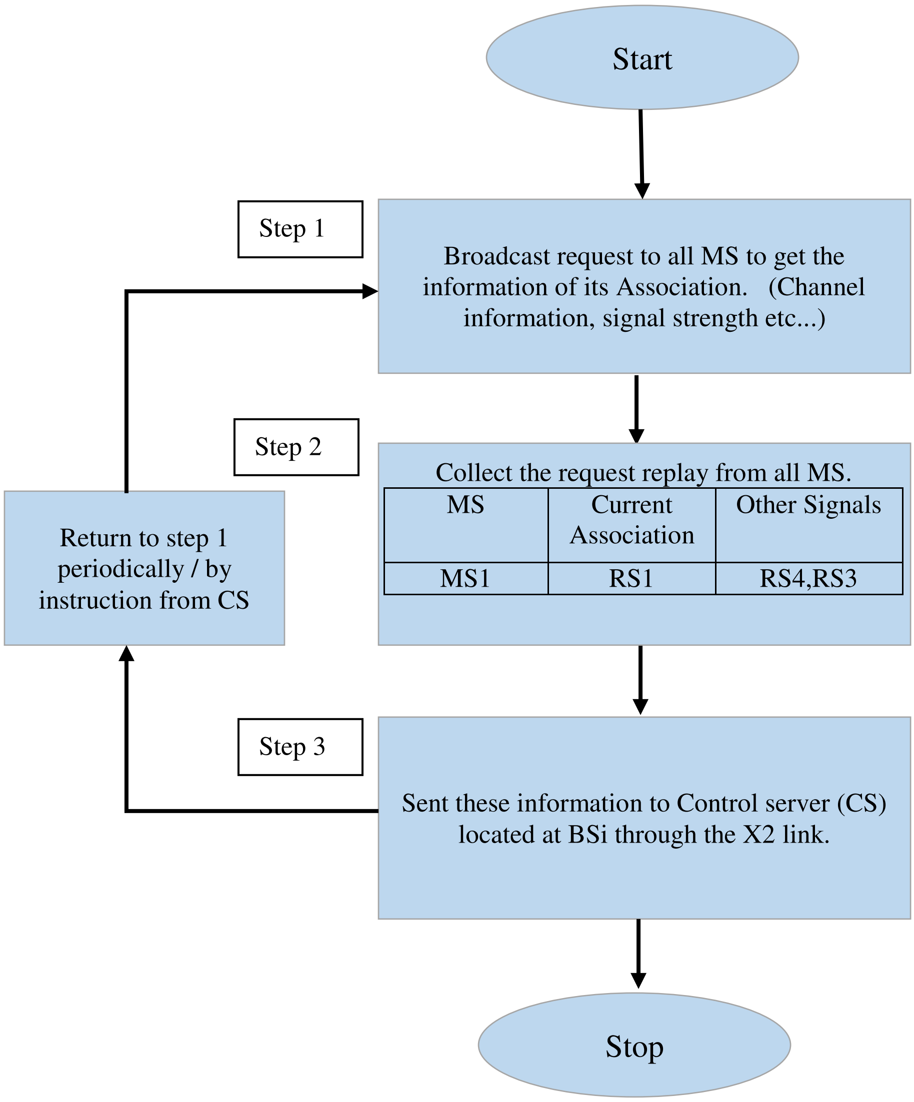

Figure-3. Process flow at relay station.

Steps to find total active MSs

- Broadcast request to obtain MSs association from all RSs through PCCH
- Collect replay to the Broadcast request
- Send the collected information to the Control server (CS) which is placed at the BS through the X2 link.
- The CS(cell Zooming server) collects the information about the user (MS) association to the corresponding RS , from all RS's deployed in its transmission area "A" through the X2 link.
- Compute iXi matrix , where i = number of RS.
- Check the diagonal elements, if any one diagonal element is "0".
- Total No:Of mobile station "N" in the area "A" of BS i is equal to sum of diagonal elements.
- $N = \sum RSij$, where $i = j$. (1)

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	RS1	RS2	RS3	RS4
RS1	12	1	2	3
RS2	1	0	5	6
RS3	2	5	22	8
RS4	3	6	8	28
RS5	4	7	9	10

$$= \begin{pmatrix} 12 & 01 & 02 & 03 & 04 \\ 01 & 00 & 05 & 06 & 07 \\ 02 & 05 & 22 & 08 & 09 \\ 03 & 06 & 08 & 28 & 10 \\ 04 & 07 & 09 & 10 & 18 \end{pmatrix}$$

Figure-4. iXi matrix.

Optimal placement of relay station

The primary objective of our work is to save energy while satisfying a certain level of service quality. There should be a tradeoff between energy saving and QoS parameters. Suburban areas with high MS densities are the most suitable places for the application of this proposed method rather than urban or rural areas. However, each suburban area has its own traffic pattern which directly determines the efficiency of this approach. Therefore before applying this methodology we have to consider following factors.

Overlaping coverage

The relay stations are to be deployed in such a way that it ensures to cover the total coverage area of the selected BS together with minimal overlapping area to each other. The mobile stations in the overlapping area will be associated to any one of the RS with respect to the grater signal strength. When powering all the RSs together, the total power consumption by the relays should be equal to or less than the consumption of the BS.

Dynamic relay station planing

Before deploying the RS, a detailed study and analysis of the transmission area need to be carried out. For example consider in a suburban region, a BS with 2 km radius coviring an area of 12.56 square kilometer (considering a circular cell area is πR^2).Let there are few non residential schools , some residential areas with normal population density, and few shops and some government offices. In an area like this in india there is probability of very less network traffic during night time. The preposed real time network traffic estimation method and power saving mode algorethem can be implimented on these type of areas efficiently.Other cosiderations to be done in these areas is mobility of MSs. For this a detail survay about roads passing through the region are to be conducted before the deployment. If there is express highways crossing by, the relays which covers these areas need to be powered always. An efficient study and analysis about the transmission area of BS before RS deployment will improve the performance of this preposed method.

A detailed study about geography of the area is also need tobe done, areas like lakes, forest etc where there is no population at all are to be considered which will also improve the performance of this preposed method.

MS mobility considarations

Possibility of mobility for each MS can be predicted by studying the details of all roads in the transmission area of a BS. We need not to be much worried about the stationary MSs located inside the transmission area of a RS, but those at the edges need a handoff to the neighboring RSs at any time. In order to do this Handoff efficiently we have to predict the possibility of mobility for each MSs by studying the ways and roads which crosses two or more RSs. If there are busy roads or highways crossing,those relays which covers these areas need to be powered always.

Relay assisted BS power saving algorithm (RABPS algorithm)

The objective of this work is to save power of the network by putting the BS in to power saving mode (PSM) and simultaneously powering low power RSs to ensure Quality of service. The performance of real time traffic estimation method which we already proposed in section 3 is very crucial for the performance of this algorithm. The number of RSs to be deployed in a BS transmission area depends on how big the area is, the maximum coverage area of RS, minimum overlapped coverage area between each RS and geographical terrains of the region. This is to be find out by proper study and analysis before deployment.

A promising technique to reduce power consumption in wireless access networks is the introduction of sleep modes where BSs are becoming inactive when no or little activity takes place in their coverage cells [5,16-19]. But for this technique an efficient method to estimate real time network traffic is required. We have already proposed an efficient method to find out real time traffic by joint deployment of relay station in section 3. The BS is not completely switched off during the sleep mode as it keeps monitoring and if necessary it can become active again. For example we can set a minimum threshold value of network traffic for BS to sleeps with respect to the total capacity of each BS, while estimating network traffic (number of active MSs) for first time, let it be less than the threshold value. Considering this the control server (CS) at BS will initiate to compute power saving mode algorithm and make BS to sleep. At another point of time when calculating the number of MSs, let the value is more than the threshold, then correspondingly BS has to be active. The method to find total number of active MSs in a selected BS is described in section 3 by equation 1.

Another technique proposed here is called relay zooming which is similar to cell zooming which adaptively adjust the cell size according to (amongst others) the traffic load. To adaptively adjust the cell size according to (amongst others) the traffic load some complex procedures and hardware is required at BS but here for relay zooming it is difficult to install such hardware in each relays as it is more expensive and more power consuming. In our work which relay to zoom and zoom out is analyzed and instructed by running the proposed algorithm at control server placed at selected BS. In this section, the proposed RABPSM algorithm, which combines these two techniques for power consumption reduction in a wireless access network, is discussed.

From the iXi matrix described in section 3 figure 4 and by equation 1, the total number of active MSs in the selected BS is calculated, if this value is below the threshold algorithm for BS power saving mode is initiated. The value of each diagonal elements gives the number of MSs associated with each relay. If any diagonal element is zero means there is no MS associated with the particular RS. To reduce power consumption of the network we can put these RS in to sleep mode until the value changes by next iterative phase. The coverage area of RS which are in sleep mode is covered by neighboring active RSs by zooming their transmission area (cell boundaries) called relay zooming. This is done similar to a cell zooming technique. After ensuring total overlapped coverage of selected BS transmission area by powering remaining RSs deployed, the BS can be put it to sleep mode of power saving mode until the next iteration phase.

This method ensures power saving by putting BS and RSs to sleep modes and good quality of service by an overlapped coverage of BS transmission area with joint deployment of relays. Proper deployment of RS by studying and analyzing factors discussed on section 4 and by efficient real time network traffic estimation the overall performance of this system can be improved.

Steps for RABPS algorithm

This algorithm can be expressed mathematically incroparating set theory as follows:

a) Check for value zero in the diagonal elements of iXi matrix
b) Identify that RSs with no mobile associated to it and put those RSs to power saving mode/Sleep mode
   Let "D" be the total number of RS Deployed
   Let "S" be the number of RS which are not associated with any MSs, which can be put in to power saving mode/sleep mode.
   Let A = number of active RS
   $A = D - S$ (2)
c) Let R_X, R_Y and R_Z be the set of total number of RSs deployed, RSs in sleep mode and active relay stations respectively.
d) Start with an element R_{Yi} of the set R_Y which is a relay station not associated to any MS.
e) Determine its closest neighboring RSs which are the elements of set R_R and form a set Rm where $R_m = \{R_j\}$, where j = 1 to M, M= the number of closest RS of $R_{Yi} \in R_Y$, where i = 1 to S
f) Zoom the transmission area of determined neighbors $R_m = \{R_1, R_2......R_M\}$..
g) Check weather transmission area of R_{Yi} is overlapped by expanding elements of $R_m = \{R_1, R_2......R_M\}$ one by one.
h) Check for solution. If solution is satisfied, return to step 4 with next element of R_Y by incrementing i = i +1
i) Continue iteration until i <= S, if all elements of R_Y is checked; put selected BS to Sleep mode.

As discussed above, the algorithm consists of a number of steps. The different steps of the algorithm is discussed in details based on the flow graph in Figure-5.

D = number of RS Deployed; S = number of RS in power saving mode and A = number of active RS; $A = D - S$;
Let R_X = $\{R_{x1}, R_{x2}......R_{xD}\}$; set of total number of RSs
Let R_Y = $\{R_{y1}, R_{y2}......R_{yS}$; set of RSs in power saving mode
Let R_Z = $\{R_{z1}, R_{z2}......R_{zA}\}$; set of active RSs
R_m = $\{R_j\}$, where j = 1 to M; set of closest relay station to R_{Yi}. M= the number of closest RS of $R_{Yi} \in R_Y$, where i = 1 to S

M is calculated for each RS after deployment of the system by theoritical study and analysis, so each RS knows the value of M by default.

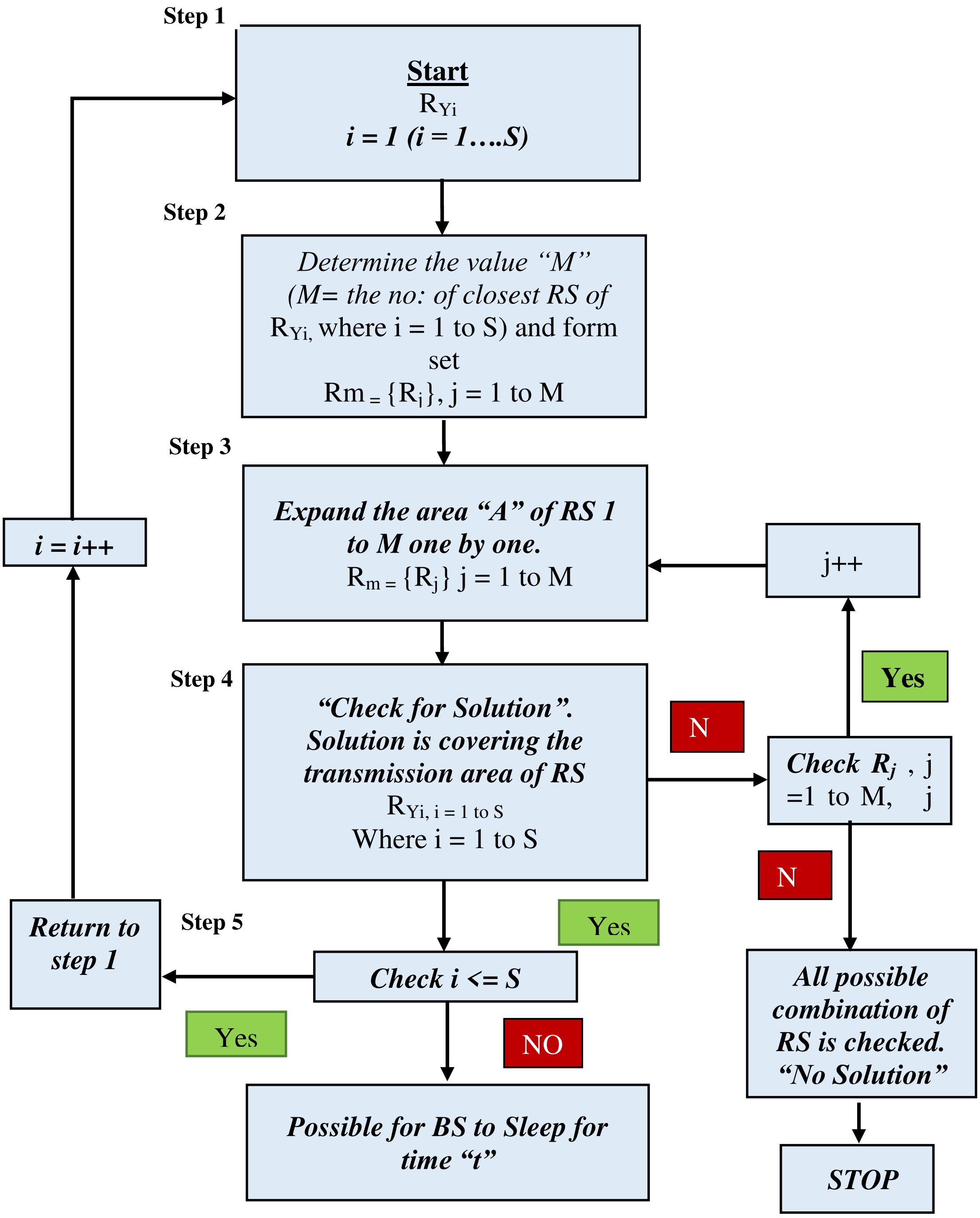

Figure-5. RABPS algorithm flow graph.

After putting a BS to sleep mode, the question need to be answered is when to wake from its sleep mode or when the selected BS need to be in active mode. To solve this problem many stratagies can be followed. Firstly with a historic data anlysis of traffic profile we can predict the peak and off peak hours of a BS and accordingly RABPS algorithm can be implimented and during the peak hours the BS should be in active mode. Secondly real time mobile traffic estimation method preposed in secton 3 need to be done frequently, when ever the value of N is grater than the threshold value "T" the BS is activated.

Efficient handoff strategy

The deployment of relay station (RS) and base stations (BS) inter connected with X2 links makes an efficient strategy for good handoff especially group handoff between BSs. Consider the deployment strategy as shown in Figure-2, the RSs R2, R3, R4 and R6 are deployed on the cell edges of BS1. These RSs covers cell edge areas of BS1 with its neighboring BSs, which means this kind of deployment can improve signal strength at the cell edges, which results in good PDR and avoid call drops during handoff. Group handoff is intimated to BS2 through the X2 link connected between B1, R1 and B2. R1

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is deployed at the cell edge of BS2 and BS1 which overlap the transmission area of both BS1 and BS2, So Efficient handoff is possible. Relay node can be switched off to minimize power after the successful handoff process.

RESULTS AND DISCUSSIONS

A network topology with nine relay stations (RSs) deployed in a BS transmission area with overlapped coverage and with random number of mobile stations (MSs) were simulated using MATLAB 2013a 8.1 version. The simulation parameters are described in Table-1. Network topology is shown in figure 6. The total number of mobile stations in the transmission area of BS is calculated by summing the diagonal elements as mentioned in section 3 and equation 1. The RSs with none of the MS associated with it is also found out by identifying the RSs corresponding to "0" diagonal elements of iXi matrix. The power rating of the selected BS is assumed as 8 kilowatts and the power rating of relay station is 0.8 watts. The transmission area of BS and each RS is assumed as 2 kilometer and 1 kilometer respectively. So for the overlapped coverage of transmission area 9 RSs are needed to deploy. The traffic profile of the selected BS is considered to be in off peak hours.

Table-1. Network simulation parameters.

PARAMETER	VALUE
Terrain Area	6000 X 6000 m^2
BS Transmission range	2 km
RS Transmission range	1 km
BS Power rating	8 kW
RS Power rating	0.8 kW
Number of RSs	9
Number of MSs	40
MS Deployment	Random

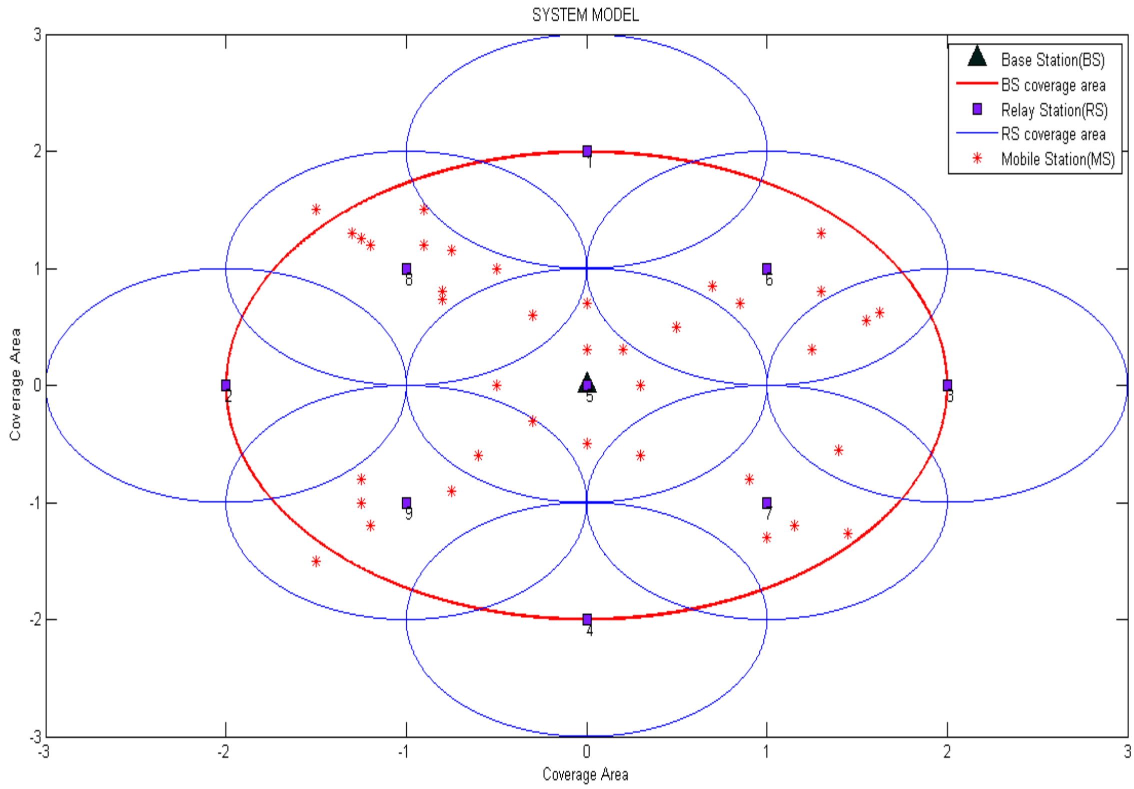

Figure-6. Network topology.

With the random distribution of MSs in the network topology shown in Figure-6 the RSs 1, 2 and 3 are not associated with any MSs. These relay stations are made to power saving modes for a time "t" until the next iteration. After analyzing the traffic profile the BS is allowed to sleep for time "t" by covering the BS transmission area with RSs. The power consumption analysis of Base station with and without the proposed RABPSM algorithm is done for one hour. During off peak hours a normal BS consumes 8000 watts per hour but the results shows with the proposed algorithm to power the transmission area of same BS with joint deployment of RS; the power consumption is only 5000 watts. Power consumption analysis with RABPS algorithm is shown in Figure-7.

For the real time traffic analysis during the initial phase of proposed RABPSM algorithm both the RSs deployed and BS is need to power together for few seconds. But after the network traffic analysis the BS and the RSs which are not associated to any MSs are made to

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sleep. The power consumption of the total system during this initial phase is higher for few seconds which is a transition period shown in Figure-8. In this simulation the simulation running time is considered as transition time of the system.

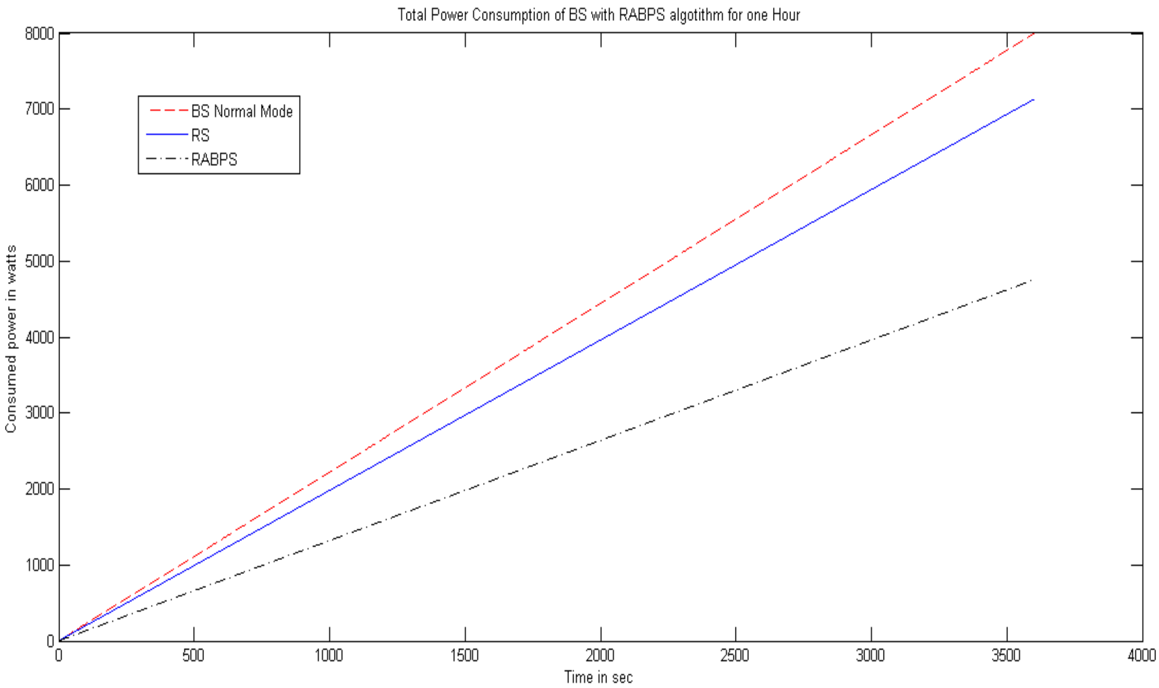

Figure-7. Total power consumption of BS with and without RABPSM algorithm.

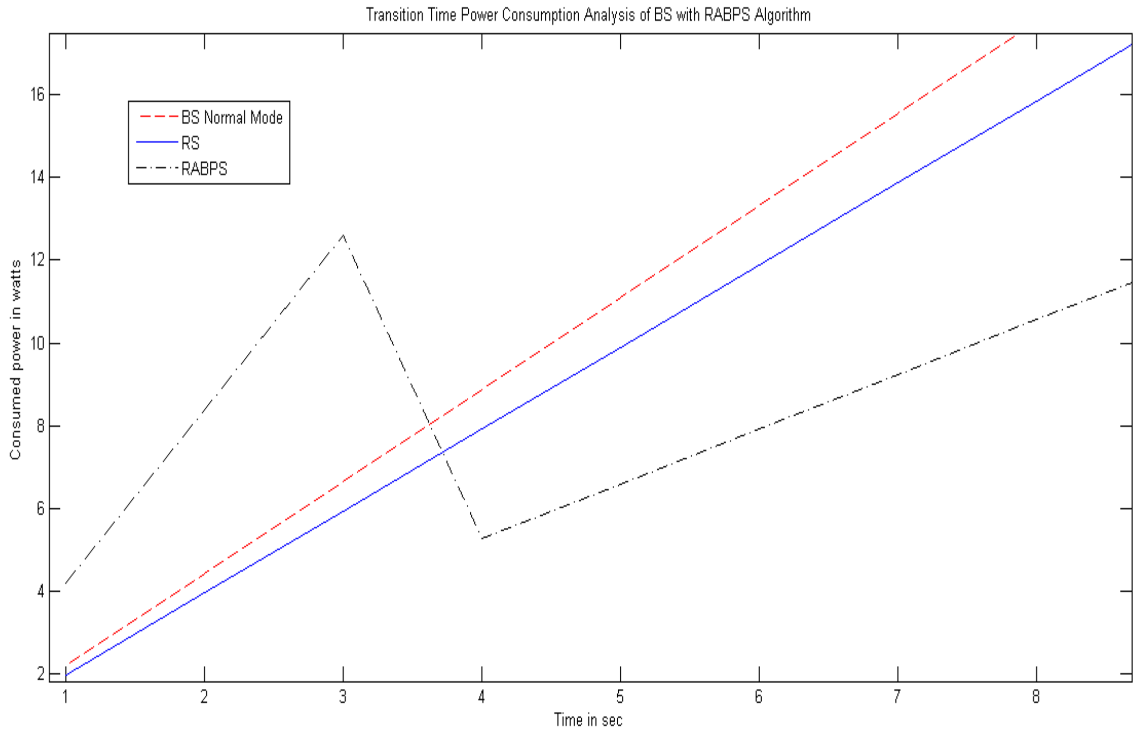

Figure-8. Transition time power analysis with RABPS algorithm.

CONCLUSIONS

In this paper we proposed a novel RABPS algorithm to optimize power consumption of radio base station by deploying low power relay stations in the transmission area of selected BS. We also proposed a method for real time network traffic estimation which can efficiently find out the traffic profile of a BS and number of MSs associated to each RS. The concept of relay zooming is also introduced in this work to optimize power. The simulation results shows that our proposed method can save an enormous amount of power for radio Base stations without affecting quality of service. The deployment of RSs on the cell edges as an efficient handoff strategy is also discussed in this work. The sleep mode algorithms for BS not only reduce power consumption of BS but also helps to decrease the emission of GHG gasses like Co_2. Our future work is to design a green BS incorporating green energy harvesting systems and reducing Co_2 emissions.

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