Introduction to Green Communication and Technology

Assignment Report

From the operator point of view, it is essential to know/decide how many and which base station should be on for meeting QoS requirement as well as to meet energy demand and OPEX budget, and which electricity supplier an user should associate with.

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***Abstract* —With the increasing energy consumption and demand due to urbanization and increasing population need for green technology has risen. For fulfilling QOS requirement and at the same time considering energy demand of a base station a heuristic approach has been used to determine Opex budget by managing user connection links. Here base station on-off and switching algorithm has been developed for an efficient Network traffic in a smart grid for saving cost and power consumption.**

Keywords — Power Consumption, OPEX Budget, Smart Grid, Network Traffic, Base Station, Users.

I. INTRODUCTION

With the increase in demand for energy in today's fast-paced world, power consumption is bound to be on the rise. The global community is concerned with this rise in energy consumption by manifold, as we slowly encroach towards using up all our available energy sources. Since more than half of the existing fossil fuels have been already consumed and the ICT sector contributes to a solid 3% of the total energy consumption, there is a pressure on the ICT sector to reduce power consumption and conserve energy. Estimates show that 0.4% of electricity is consumed by the Internet categorically in broadband-enabled countries. This ratio is predicted to increase to 1% even though there have been improvements in the energy efficiency of network equipment, and increased energy savings by employing optical bypass and multicast. The main reason for this rise is a consequence of increased access rates. The energy consumption per bit of data on the Internet is around 75 J at low access rates and decreases to around 2–4 J at an access rate of 100 Mb/s.

In the last few years, India has witnessed an exponential growth in mobile subscribers and subscriber additions are currently taking place at over 6 million subscribers every month. However, this aggressive growth is at present limited to the urban and semi-urban areas and the vast population in the rural areas is still to receive and enjoy the benefits of mobile connectivity. To fulfil the quality of service for this vast number of subscribers, more number of base stations can be a solution, but as we know every coin has two faces, this also brings in ever-increasing energy consumptions and carbon footprint to the mobile communications industry. So we came upon a solution of using ON/OFF switching algorithm by which we can reduce power consumption whilst maintaining the quality of service, by switching the Base Stations ON or OFF based on the requirements.

This is an attempt aiming to reduce energy consumptions and OPEX of a Cyber Hub area using a smart grid model. A Smart grid is a technological marvel which considers a variety of energy efficient operations and measures to reduce peak-time power consumption by properly arranging the Base Station supply points according to the current network traffic demands. They empower energy to the consumers according to fluctuating rates of traffic. A general Cyber Hub has the highest traffic rate during the day, medium in the morning, and lowest at night. To achieve the goal of lowest energy consumption, it is essential for the operator to decide how many and which base stations should be kept ON at a particular time, for meeting the QoS requirement as well as to meet the energy demand and OPEX budget, and which energy supplier an user should associate with. The OPEX budget, or operating expenses, is the continuous cost required to keep a system operating. This Capacity Limited Network consists of Base Stations, subject to be switched off during low traffic conditions, i.e. when the supply point is idle. When a Base Station is switched off, the users associated with the same is supported by another base station, and hence, the Base

Stations have flexible and dynamic cell coverage capacity. They are classified as Micro-cell or Macro-cell coverage.

II. Proposed Solution

A. *System Analysis and Possible Applications*

This model can be used by an operator to efficiently distribute energy to consumers in a Cyber Hub Area, to meet the requirements of QOS and OPEX, for varying traffic rates. Traffic rates in a cyber hub area is expected to range in the highest traffic rate values during the day, medium rate in the mornings and lowest at night.

We designed an area matrix for the cyber hub area with each cell denoting the total requirement of all the users in the corresponding user point, and randomly distributed Macro and Micro Base Station locations, capable of covering all the user points. We have considered varying network traffic depending on the time of the day. This coverage oriented model attempts to provide energy to all the users from a single Macro base station with large coverage, during low traffic density. During higher traffic rates, smaller Micro base stations are used as suppliers and are made to reach their maximum capacity. Base stations that are idle are switched off. Users coming under coverage areas of multiple Base Stations are made to access from the Base Station which is nearer to reach its maximum capacity. The base stations have flexible coverage and can be made to support a varying number of users at different times. This design helps us achieve maximum energy efficiency at changing traffic rates. The model makes sure every user is associated with at least one access at every instant, hence there is no compromise with the Quality of Service. Opex minimisation, from the operator point of view, requires an efficient distribution of energy among the users, which includes a significant reduction of operating sites and multitasking. Automatic equipment switching according to the current existing demands helps to suppress the total energy consumption.

B. Mathematical Model of System

Network Traffic Rates denote the amount and type of traffic on a particular network at a certain instant. Traffic rates are proportional to the total users in the area requiring data bit rate. Rates can be classified as High Traffic (1 - 9 Mbps), Medium Traffic (1 - 6 Mbps) or Low Traffic (1 - 2 Mbps). At low traffic hours, a single Macro Base Station can support all the users in a Cyber Hub area, switching OFF all the other base stations in idle/standby mode, whereas, when traffic increases, the Micro Base Stations are dynamically switched ON due to presence of user access in Peak Time. Every Base station attempts to reach full capacity utilisation, with possibility of variation in coverage area, so that base stations in minimum use may be switched off, aiming to reduce the total energy consumption and Operational Costs. The state of a Base Station (BS) may be represented by

ON: 1

OFF: 0

1. User association

$$x_{k,j} = \begin{cases} 1, & User\ k\ is\ connected\ to\ \mathrm{B}S\ j \\ 0, & Otherwise \end{cases},$$

$$k = 1, 2, 3, \ldots\ldots\ldots\ldots\ldots, K$$

$$j = 1,2,3, \ldots\ldots\ldots\ldots\ldots, J$$

2. Base Station status

$$\mathrm{y_j} = \begin{cases} 1, \mathrm{BS\ turned\ on} \\ 0, \mathrm{BS\ turned\ off} \end{cases}$$

$$j = 1,2, \ldots\ldots\ldots\ldots\ldots, J$$

$$y_{\mathrm{j}} = Base\ station\ status$$

3. Upper bound of weight of base station

$$\sum_{\mathrm{j}=1}^{\mathrm{J}} \sum_{\mathrm{k}=1}^{\mathrm{K}} \mathrm{y_j}(\mathrm{x_{ij}^{weight}}) \leq \overline{\mathrm{y_j}}$$

$$x_{i,j}^{weight}$$

$$= QoS\ requirement\ of\ user\ k\ connected\ to\ bs\ j$$

$$\overline{y_{\mathrm{j}}} =$$

$$Upper\ bound\ of\ base\ station\ weight$$

4. OPEX Cost

$$OPEX\ Cost = C_0 + C_1 + C_2 + \mathrm{C_3 N_k}$$

$$C_0 = Site\ base\ cost$$

$$C_1 = O/M\ Cost$$

$$C_2 = Power\ Cost$$

$$C_3 = Cost\ of\ transmission\ per\ link$$

$$\mathrm{N_k} = \mathrm{No.\ of\ links\ connected\ to\ kth\ BS}$$

C. *Working Platform*

The simulations for the proposed solution are done using MATLAB R2018b and we have derived the desired results for reducing power consumption and OPEX budget.

D. Algorithm

Algorithm followed in this work has been described through the below mentioned flowchart.

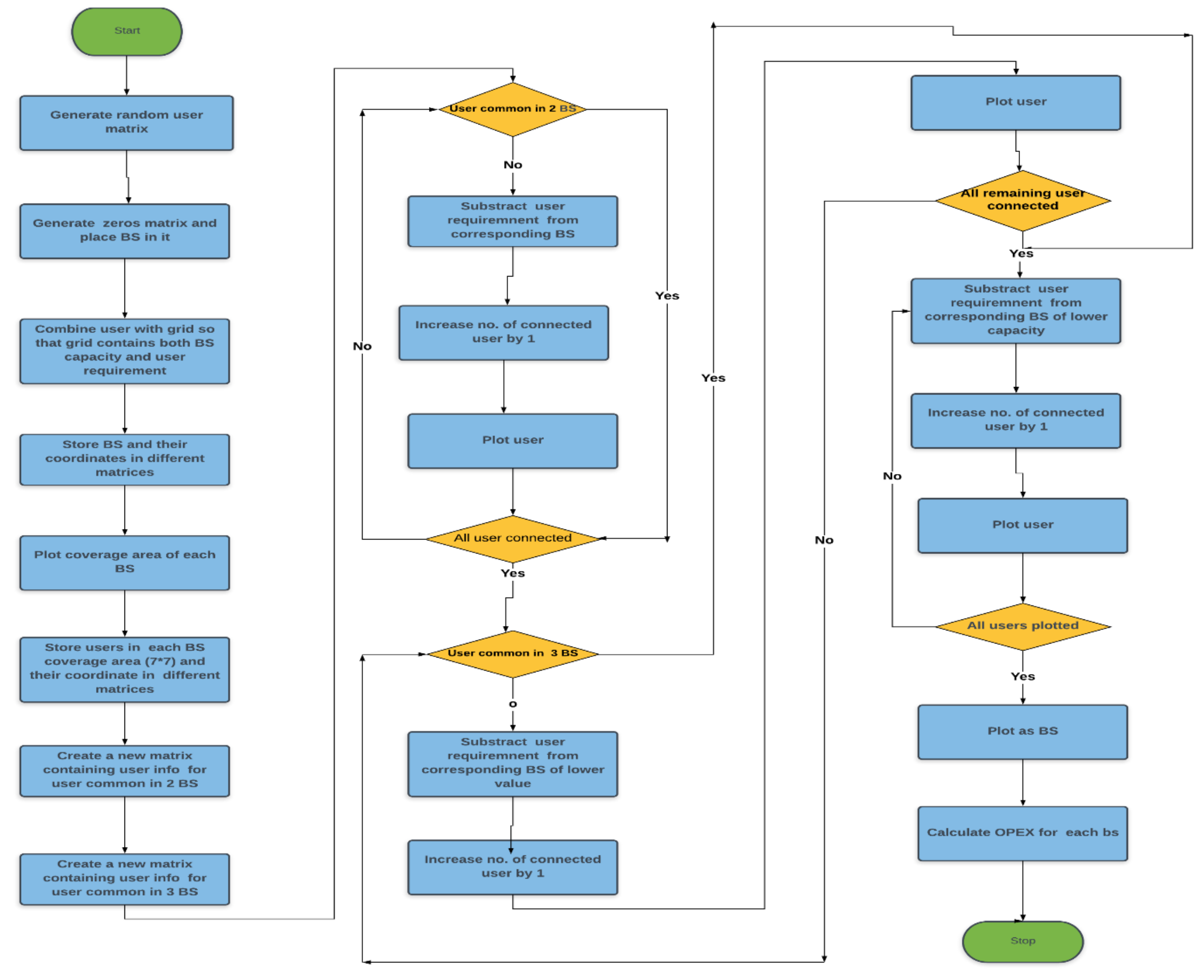

Figure 1: Flowchart for the Algorithm used

III. MATLAB SIMULATIONS AND RESULTS.

A. Code

The following formulated model gives the total power consumption and OPEX budget for the Base Stations in a cyber hub area, for various traffic level requirements, from the operator point of view.

Given below are MATLAB codes for medium traffic taking user requirements in the range 1-6Mbps. Similarly, for low traffic situation user requirements can be considered as 0-2Mbps and for high traffic as 5-10Mbps.

macro_medium.m

```
clc;
clear all;
close all;

grid = randi(6,15);                     %Randomly user distribution in
a 15x15 area for medium traffic distribution
umax = max(max(grid));            %Maximum user requirement

grid(8,8) = 2500;           %Placing BS at randomly selected location

figure,                 %Plotting the grid
rectangle('Position',[0.5 0.5 15 15],'EdgeColor','y');
      %Marking outer boundary of the grid
xlim([0 16]);               %Limiting the x-axis of the plot
ylim([0 16]);               %Limiting the y-axis of the plot
hold on;

bs = [grid(8,8),0,0];
for i = 1:15
    for j = 1:15
        if ~eq(i,8) || ~eq(j,8)
            bs(1) = bs(1) - grid(i,j);             %Subtract user
requirement from remaining BS capacity
            bs(2) = bs(2) + 1;             %Add 1 to number of users
connected
            plot(i,j,'k.');             %Plot user as black dot
            hold on
        end
    end
end
plot(8,8,'rs','MarkerFaceColor','r');              %Plot BS  as square
title('Locations and Distribution of Users and BSs');
hold off
```

```
equipment = 50;         %Initial Investment - Equipment Cost
site_buildout = 70;         %Initial Investment - Site Buildout Cost
site_installation = 30;         %Initial Inveatment - Site Installation
Cost
initial_cost = equipment + site_buildout + site_installation;
operation_maintenance = 3;          %Annual Operation and Maintenance
Cost
site_lease = 10;         %Annual Site Lease
transmission_per_connection = 5;            %Annual Cost for
Transmission to 1 connection
annual_cost = operation_maintenance + site_lease;
trc = transmission_per_connection * bs(2);         %Total transmission
Cost for each BS
bs(3) = initial_cost + annual_cost + trc;          %Total charges for
each BS
X = [initial_cost, annual_cost, trc];
figure,
pie(X,{'Initial','Annual','Transmission'});         %Plotting Pie Chart
showing cost distribution per BS
title('OPEX distribution');
```

micro_medium.m

```
clc;
clear all;
close all;

user = randi(6,15);                     %Randomly user distribution in
a 15x15 area for medium traffic distribution
umax = max(max(user));             %Maximum user requirement

grid = zeros(15,15);               %Area matrix
grid(4,4) = 450;             %Placing BSs at randomly selected locations
grid(2,9) = 450;
grid(4,12) = 450;
grid(10,1) = 450;
grid(14,4) = 450;
grid(9,7) = 450;
grid(15,11) = 450;
grid(11,14) = 450;
grid(15,15) = 450;

c = 1;                 %Combining user distribution matrix with BSs and
forming 15x15 grid
for i = 1:15
    for j= 1:15
        if grid(i,j)==0                %Placing user requirement
values in the grid
          grid(i,j) = user(i,j);
        else
          b(c) = grid(i,j);              %Storing BS value in a array
          xbs(c) = i;              %BS x-coodrinates array
          ybs(c) = j;              %BS y-coodrinates array
          c = c + 1;
```

```
        end
    end
end
nbs = length(b);             %Total number of BSs available in grid
bs = [b;zeros(2,nbs)];             %Matrix for BS capacity, no of users
supported and opex cost

figure,                %Plotting the grid
for i = 1:nbs
    rectangle('Position',[xbs(i)-3.5 ybs(i)-3.5 7 7],'EdgeColor','y');
                 %Marking the area covered by each BS
end
rectangle('Position',[0.5 0.5 15 15],'EdgeColor','y');
      %Marking outer boundary of the grid
xlim([0 16]);                %Limiting the x-axis of the plot
ylim([0 16]);                %Limiting the y-axis of the plot
hold on;

for k = 1:nbs                %For each BS
    c = 1;
    for pa = xbs(k)-3:xbs(k)+3                %Considering a 7x7
coverage area
        for qa = ybs(k)-3:ybs(k)+3
            if pa > 0 && qa > 0 && pa <= 15 && qa <= 15
      %Considering BS with coverage range inside working area
                if (pa == xbs(k) && qa == ybs(k))
      %Ignoring BS coordinates
                    continue;
                else
                    if grid(pa,qa) > umax                %Considering
other BSs lie inside coverage area of this BS
                        bgroup(k,c) = nan;
                        xcod(k,c) = nan;
                        ycod(k,c) = nan;
                        agroup(k,c) = nan;
                    else
                        bgroup(k,c) = grid(pa,qa);             %User
requirement values around the BS entered in each row
                        xcod(k,c) = pa;            %x-coordinate of
corresponding user in bgroup
                        ycod(k,c) = qa;            %y-coordinate of
corresponding user in bgroup
                        agroup(k,c) =
str2num([num2str(pa*10+qa),num2str(abs(pa*10-
qa)),num2str(grid(pa,qa))]);            %Coded values using coordinates
and user requirement such that values are not same for two different
users
                    end
                end
            else                                                %Considering
coverage range of BS outside working area - all values are taken as
NaN)
                if (pa == xbs(k)) && (qa == ybs(k))
                    continue;
                else
                    bgroup(k,c) = nan;
                    xcod(k,c) = nan;
                    ycod(k,c) = nan;
```

```
                    agroup(k,c) = nan;
                end
            end
            c = c+1;
        end
    end
end
len = length(bgroup);              %Length of rows of users under BS
coverage area matrix

C2 = nan(1,len+2);                 %Initialising the matrix containing
users in overlap area of BSs taking two at a time by row of NaN
if ~isempty(agroup)                %Check if agroup (matrix containing
coded values about users) is empty or not
    a = 1;
    for i = 1:nbs-1
        for j = i+1:nbs
            y = intersect(agroup(i,:),agroup(j,:));       %Finding
overlap points between two BSs
            if ~isempty(y)               %Intersect is present or not
                C2(a,:) = [i,j,y,zeros(1,len-length(y))];
      %Storing BS numbers (column 1 and 2) and common user codes
                a = a + 1;
            end
        end
    end
end

C3 = nan(1,len+3);                 %Initialising the matrix containing
users in overlap area of BSs taking three at a time by row of NaN
if ~isnan(C2)                %Check if C2 (matrix containing user codes
common in two BSs) is empty or not
    a = 1;
    for i = 1:size(C2,1)
        for j = i+2:nbs
            if C2(i,1) < j && C2(i,2) < j
                y = intersect(C2(i,2:length(C2)),agroup(j,:));
      %Finding overlap points between three BSs
                if ~isempty(y)               %Intersect is present or
not
                    C3(a,:) = [C2(i,1),C2(i,2),j,y,zeros(1,len-
length(y))];                %Storing BS numbers (column 1 and 2) and
common user codes
                    a = a + 1;
                end
            end
        end
    end
end

color = [0 0.25 0.25; 0.5 0 0.5; 0 0.75 0.25; 0 0 1; 0 1 0; 0 1 1; 1 0
0; 1 0 1; 0.75 0.9 0.15];              %Matrix containing RGB colour
values for plotting users

for i = 1:nbs
    for j = 1:len
        if ~(ismember(agroup(i,j),C2(:,3:length(C2))))
      %Check if user is common in two BS or not
```

```
            if bgroup(i,j) > 0 && bs(1,i) >= bgroup(i,j)             %If
user lies in only one BS coverage area, check it is not greater than
remaining BS capacity value
              bs(1,i) = bs(1,i) - bgroup(i,j);
      %Subtract user requirement from remaining BS capacity
              bs(2,i) = bs(2,i) + 1;                %Add 1 to number of
users connected
            end
              plot(xcod(i,j),ycod(i,j),'k.');             %Plot user as
black dot
              hold on
              plot(xcod(i,j),ycod(i,j),'o',
'MarkerEdgeColor',color(i,:));               %Plot user connected to
different BS in different colours as circle
              hold on
            end
        end
    end
end

if ~isnan(C2)                %Check if users common in two BS are
present or not
    for i = 1:size(C2,1)
        b1 = C2(i,1);              %BS number 1 for which common users
are taken
        b2 = C2(i,2);              %BS number 2 for which common users
are taken
        for j = 3:length(C2)
            arr = [bs(1,b1),bs(1,b2),0];                 %Creating
array containing BS capacity of both BS and zero at place of user
requirementarr = [0,0,0];
            arr2 = [bs(2,b1),bs(2,b2)];            %Creating array
containing number of users connected to each BS
            if ~eq(C2(i,j),0)
                if ~(ismember(C2(i,j),C3(:,4:length(C3))))
      %Check if user is common in three BS or not
                    q = find(agroup(b1,:) == C2(i,j));
      %Find position of user code in b1 row of agroup matrix
                    u = bgroup(b1,q);              %User requirement
for searched user code
                    arr(3) = u;         %Inserting user requirement to
the array
                    sorted_ar = sort(arr);              %Sort arr
                    g = find(sorted_ar == u);           %Find user
position in sorted array
                    if g < 3           %If user requirement is greater
than both BS capacities, then skip
                        h = find(arr == sorted_ar(g(1)+1));
      %Find BS position with lower capacity in unsorted array
                        arr(h(1)) = arr(h(1)) - u;
      %Subtract user requirement from BS with lower capacity
                        arr2(h(1)) = arr2(h(1)) + 1;
      %Add 1 to number of connected users for BS with lower capacity
                        plot(xcod(b1,q),ycod(b1,q),'m.');
      %Plot user as magenta dot
                        hold on
                        plot(xcod(b1,q),ycod(b1,q),'o',
'MarkerEdgeColor',color(b1,:));              %Plot user connected to
different BS in different colours as circle
```

```
                        hold on
                    end
                end
                bs(1:2,b1) = [arr(1),arr2(1)];                %Enter
final calculated values to BS data matrix for b1
                bs(1:2,b2) = [arr(2),arr2(2)];         %Enter final
calculated values to BS data matrix for b2
            end
        end
    end
end

if ~isnan(C3)                %Check if users common in three BS are
present or not
    for i = 1:size(C3,1)
        b1 = C3(i,1);             %BS number 1 for which common users
are taken
        b2 = C3(i,2);             %BS number 2 for which common users
are taken
        b3 = C3(i,3);             %BS number 3 for which common users
are taken
        for j = 4:length(C3)
            arr = [bs(1,b1),bs(1,b2),bs(1,b3),0];
      %Creating array containing BS capacity of both BS and zero at
place of user requirement
            arr2 = [bs(2,b1),bs(2,b2),bs(2,b3)];
      %Creating array containing number of users connected to each BS
            if ~eq(C3(i,j),0)
                q = find(agroup(b1,:) == C3(i,j));            %Find
position of user code in b1 row of agroup matrix
                u = bgroup(b1,q);            %User requirement for
searched user code
                arr(3) = u;        %Inserting user requirement to the
array
                sorted_ar = sort(arr);            %Sort arr
                g = find(sorted_ar == u);              %Find user
position in sorted array
                if g == 4             %If user requirement is greater
than both BS capacities, then skip
                    continue;
                end
                h = find(arr == sorted_ar(g(1)+1));           %Find BS
position with lower capacity in unsorted array
                arr(h(1)) = arr(h(1)) - u;              %Subtract user
requirement from BS with lower capacity
                arr2(h(1)) = arr2(h(1)) + 1;            %Add 1 to
number of connected users for BS with lower capacity
                plot(xcod(b1,q),ycod(b1,q),'c.');             %Plot
user as cyan dot
                hold on
                plot(xcod(b1,q),ycod(b1,q),'o',
'MarkerEdgeColor',color(b1,:));            %Plot user connected to
different BS in different colours as circle
                hold on
            end
            bs(1:2,b1) = [arr(1),arr2(1)];              %Enter final
calculated values to BS data matrix for b1
```

```
            bs(1:2,b2) = [arr(2),arr2(2)];          %Enter final
calculated values to BS data matrix for b2
            bs(1:2,b3) = [arr(3),arr2(3)];          %Enter final
calculated values to BS data matrix for b3
        end
    end
end
for i = 1:nbs

plot(xbs(i),ybs(i),'s','MarkerEdgeColor',color(i,:),'MarkerFaceColor',c
olor(i,:));            %Plot different BS in different colours as
square
    hold on;
    title('Locations and Distribution of Users and BSs');
end
hold off

equipment = 20;          %Initial Investment - Equipment Cost
site_installation = 15;          %Initial Inveatment - Site Installation
Cost
initial_cost = equipment + site_installation;
operation_maintenance = 1;          %Annual Operation and Maintenance
Cost
site_lease = 3;          %Annual Site Lease
transmission_per_connection = 5;            %Annual Cost for
Transmission to 1 connection
annual_cost = operation_maintenance + site_lease;
for i = 1:nbs
    trc(i) = transmission_per_connection * bs(2,i);          %Total
transmission Cost for each BS
    bs(3,i) = initial_cost + annual_cost + trc(i);          %Total
charges for each BS
end

total_opex_grid = sum(bs(3,:));          %Total Opex for entire grid
figure,
X = (bs(3,:));          %Plotting Pie chart showing contribution of
each BS
pie(X,{'BS 1','BS 2','BS 3','BS 4','BS 5','BS 6','BS 7','BS 8','BS
9'});
title('CONTRIBUTION OF EACH BS ON TOTAL OPEX');

figure,
for i = 1:nbs
    X = [initial_cost, annual_cost, trc(i)];
    subplot(3,3,i)          %Plotting Pie Chart showing cost
distribution per BS
    pie(X,{'Initial','Annual','Transmission'});
    title(['BS ',num2str(i)]);
end
sgtitle('OPEX DISTRIBUTION FOR EACH BS');
```

B. Results

According to MATLAB simulation of the algorithm worked out Figure 2 and Figure 4 depicts the dynamic cell coverage by macro and micro base stations respectively over the users in order to minimize opex cost and ensure the user QoS requirement along with energy demand. Figure 3 and Figure 6 shows OPEX distribution of each base station with respect to Initial installation costs, annual lease and transmission charges. The distribution of total OPEX among all micro base stations is depicted in Figure 5. In Table I calculated OPEX cost has been shown.

TABLE I: SIMULATION OUTPUT FOR BASE STATION CAPACITY, USER CONNECTIONS AND OPEX DISTRIBUTION FOR A GIVEN SITUATION.

BASE STATION	REMAINING CAPACITY	NO. OF CONNECTIONS	OPEX BUGDET
MACRO	1700 (initial capacity 2500)	224	1283
MICRO (initial capacity 450)			
MICRO 1	432	15	64
MICRO 2	293	48	279
MICRO 3	310	37	274
MICRO 4	318	16	229
MICRO 5	04	08	79
MICRO 6	294	43	254
MICRO 7	333	28	179
MICRO 8	378	21	144
MICRO 9	450	0	39
TOTAL FOR MICRO BSs		216	1541

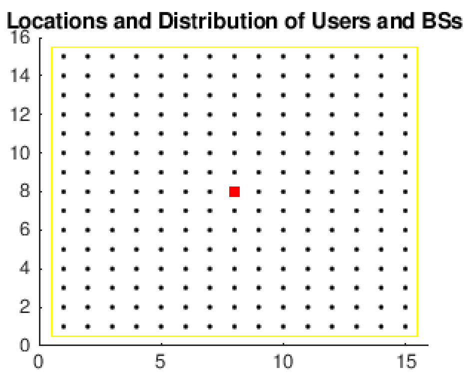

Figure 2: Users and BS distribution for Macro BS grid

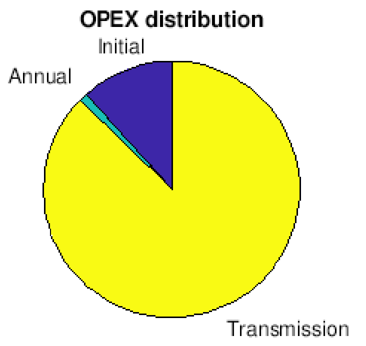

Figure 3: Factor-wise OPEX distribution for Macro BS

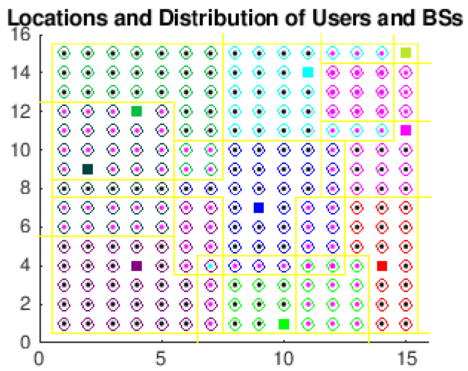

Figure 4: User and BS distribution for Micro BS grid

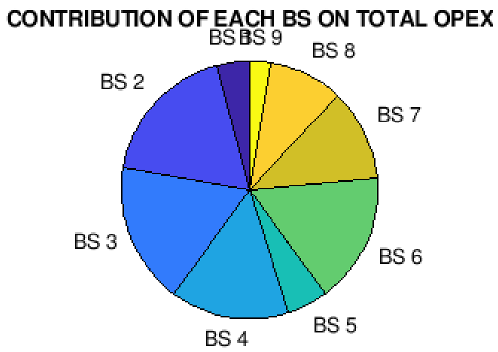

Figure 5: Contribution of each micro bs in total OPEX

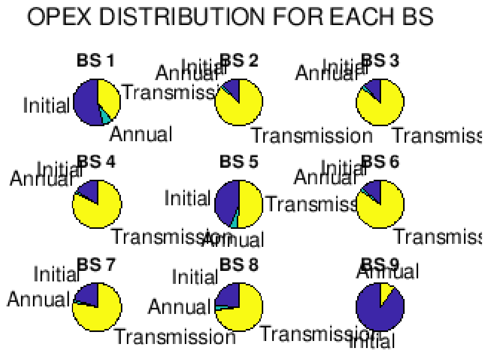

Figure 6: Factor-wise OPEX distribution for each micro bs

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We thank Mr. Purnendu Karmakar for providing us this opportunity to explore possible research in Green Communication technology, with practical approach and guiding us every way.

CONCLUSIONS

Approach used in this paper gives appropriate results. Number of users associated with the base station determine the Opex cost. Base Station switching on-off is an efficient way to reduce the Opex Cost as well as saving energy which contributes to Green Technology, thus the approach used in this work which gives priority to singly connected users is useful in practical situations especially for a cyber hub.

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Contributions by members in the report:

1. **Pankhuri Vanjani**: Researched and studied the problem statement; Developed the algorithms, model used for coding and the report outline;
2. **Pragya Jha**: Worked majorly on coding part and results.
3. **Rajrupa Roy Chowdhury**: Involved in code debugging and majorly report writing.
4. **Sharwan:** Handled the introduction part in report and formatting of formulae used in report according to requirement.
5. **Sanyam Arora**: Converted flow chart from pen paper to digital form with help of proper tool.
6. **Yogesh Modi**: Contributed in Introduction and referencing in report.
7. **K. Sankararaman**: Proofread the report for grammatical and syntax errors and helped in introduction.