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TRAFFIC AWARE CELLULAR BASE STATION POWER SCHEDULING FOR GREEN COMMUNICATION NETWORKS

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Abstract—**In different components of the smart city infrastructure the communication network is one of the essential components. This component is also a grate energy consumer, and the demand of energy is also growing continuously. But when the base stations are ideal then a significant amount of energy is being waste. Therefore, in this paper a detailed study of the cellular traffic pattern of the cellular base station has been performed. Additionally, the actual energy utilization of base stations has been measured. Based on the theoretical analysis the amount of waste energy in different scenarios has been measured. The results demonstrate the 90% of energy is being wasted when the base station is working on their full capacity all time. Additionally, when the base stations are working at peak load basis then about 54% of energy is being wasted. Based on the experimental analysis, visualization, and observations some essential facts have been recovered which is needed to incorporate when we are designing an energy scheduling system for the base stations.**

Keywords—**Data analytics, Green AI, Green Computing, Machine Learning, Smart city.**

I. INTRODUCTION

Smart cities are the future of human sustainability and lifestyle [1]. It involves different technologies like sensors and machine learning for collection and processing the data collected from citizens, buildings, and events [2]. It is essential because the knowledge is required to manage smart city resources and services[3]. In all these activities, appropriate execution of smart city services communication and electrical energy infrastructure is playing an essential role. Additionally, the utilization of both the resources i.e. electric power and efficient communication is increasing day by day [4]. However, electrification of the different services like transport and others are essential for improving the green lifestyle, but preservation of electricity is also necessary [5].

In this context, the execution of cellular network infrastructure requires a significant amount of electrical energy [6]. Additionally, as the cellular network infrastructure is growing the power demand of cellular network is increasing in similar ratio [7]. However, it is essential to improve the communication services, but wastage of electric energy is also needed to be prevent [8]. In this context, this paper is motivated to study and explore the pattern of traffic demand in cellular base stations. Therefore, in this paper first a historical dataset of cellular traffic has been considered additionally a detailed analysis of the network traffic has been carried out. Additionally, it is also tried to formulate the power demand of the network base stations.

II. TRAFFIC DATASET

The experimental dataset is collected from the Kaggle [9]. This dataset consists of traffic load of cellular base stations per hour. It means if a base station is serving u number of users in an hour, and each user consuming d amount of data, then the total consumed amount of data T_d is:

$$T_d = u * d \qquad (1)$$

The T_d is given in the dataset as Traffic. The dataset consists of four attributes namely date, hour, cell name and Traffic. The first five samples of the dataset is demonstrated in Fig. 1.

	Date	Hour	CellName	Traffic
0	10/23/2017 0:00	7	Cell_001803	15.13867
1	10/23/2017 0:00	2	Cell_002303	2.05516
2	10/23/2017 0:00	7	Cell_004083	71.55308
3	10/23/2017 0:00	0	Cell_003781	557.98491
4	10/23/2017 0:00	3	Cell_000112	0.98166

Fig. 1. Raw Dataset Sample

The dataset contains two attributes with the time information therefore we are trying to combine both the information. In this context, both the columns are converted into date time format first. Then the date field and hour field are combined. After combining both the attributes a new attribute is included into the dataset. Additionally, both the old information is removed from the dataset. Now the dataset has the final three attributes as given in Fig. 2. Next, the dataset is converted into the time series format.

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	CellName	Traffic	datetime
0	Cell_001803	15.13867	2017-10-23 07:00:00
1	Cell_002303	2.05516	2017-10-23 02:00:00
2	Cell_004083	71.55308	2017-10-23 07:00:00
3	Cell_003781	557.98491	2017-10-23 00:00:00
4	Cell_000112	0.98166	2017-10-23 03:00:00

Fig. 2. Dataset sample after merging date and hour

Therefore, the 'date-time' attribute is assigned as the index column. In addition, the cell name is complex to recognize and utilize thus a label encoder has been used to encode the cell name into relevant a numerical value. After cell name encoding and transforming date-time attribute to index the final preprocessed data [10] is demonstrated in Fig. 3.

datetime	CellName	Traffic
2017-10-23 07:00:00	20	15.13867
2017-10-23 02:00:00	32	2.05516
2017-10-23 07:00:00	44	71.55308
2017-10-23 00:00:00	33	557.98491
2017-10-23 03:00:00	1	0.98166

Fig. 3. Final preprocessed dataset Samples

The final preprocessed dataset contains two main attributes namely cell name and traffic. Additionally, it has a date and time-based index. Based on the encoding a total of 57 base station's data is available in this dataset for 1 year time duration. Here, first we are trying to measure the total amount of traffic passed through the base stations. Thus, the following steps are used:

1. Group dataset based on cell name.
2. For each base station in group
   a. Calculate sum of traffic using:

$$T = \sum_{i=0}^{N} T_i$$

Where, N is the number of samples, and T_i is the i^{th} sample of the dataset.

   b. Add total traffic T in a list named as BS
3. Return BS as a list of total traffic of the base stations.

Calculated total traffic for each base station is demonstrated in Fig. 4. In this diagram, X axis contains the base station names and Y axis contains the total traffic of the base station. According to this diagram some of the base stations are wearing huge loads while some of the base stations are serving low amounts of traffic. Therefore, as a next step we are grouping the base stations according to the traffic load of the base stations [11]. In this context, we assume there are three groups namely high traffic group, mid traffic group and low traffic group.

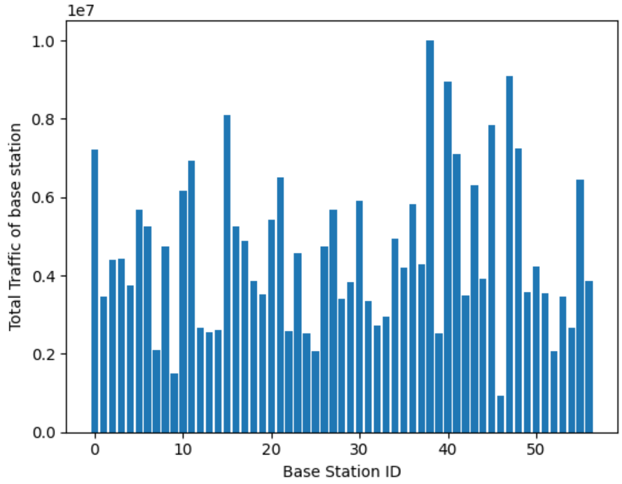


Fig. 4. Total Traffic of the base stations

In this context, first we find the maximum traffic T_{max} of the base station. Additionally, the following steps as given in table 1 are applied to group the base stations according to the traffic load.

Table 1 Steps of base station grouping

Input: BS list of base station total traffic, maximum traffic T_{max} **Output:** High traffic group H, Mid traffic group M and Low Traffic Group L
Process: 1. $for(i = 0; i < BS.ElementCount; i++)$ a. $if\ BS_i.TotalTraffic < T_{max} * 0.33$ i. $L.Add(BS_i)$ b. $if\ BS_i.TotalTraffic > T_{max} * 0.33\ and\ BS_i.TotalTraffic < T_{max} * 0.66$ i. $M.Add(BS_i)$ c. $if\ BS_i.TotalTraffic > T_{max} * 0.66$ i. $H.Add(BS_i)$ d. End if 2. End for 3. Return L, M and H

According to the given steps if the base station's traffic load is less than 33% of the maximum traffic T_{max} then it is included into low traffic group L, next if the base station's traffic between 33% and 66% of maximum traffic load T_{max} then this base station is included into mid traffic group L. Finally, if the total traffic of base station is greater than 66% of maximum total traffic T_{max} then it is included into high traffic load group H. The outcome of this process is given in Table 2. According to the results of the group we found there are only 9 base stations which are highly loaded, 14 have less traffic load and 33 base stations are serving in medium traffic range.

Table 2 total traffic based base station group

High Traffic Group H	
Total Base stations	9
Base station names	0, 11, 15, 38, 40, 41, 45, 47, 48
Mid Traffic Group M	
Total Base stations	33
Base station names	1, 2, 3, 4, 5, 6, 8, 10, 16, 17, 18, 19, 20, 21, 23, 26, 27, 28, 29, 30, 31, 34, 35, 36, 37, 42, 43, 44, 49, 50, 51, 53, 55
Low Traffic Group L	
Total Base stations	14
Base station names	7, 9, 12, 13, 14, 22, 24, 25, 32, 33, 39, 46, 52, 54

Now, to explore the pattern of traffic more precisely from each group of base stations one base station has been selected. Therefore, using table 2 base station 11 is selected as high traffic group base station. Base station 10 is selected from the mid traffic group and base station 9 is selected as high traffic group base station. The separated base station's data is sorted according to the date time or index column. Additionally visualized the complete data using Fig. 5.

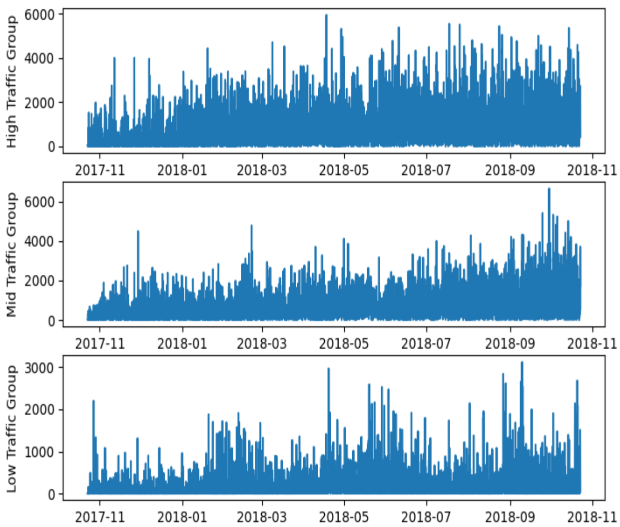


Fig. 5. Selected base station's traffic pattern

Fig. 5 contains three sub diagrams for high, mid, and low traffic group base stations for complete one year. In each diagram X axis shows the date and Y axis contains the traffic of the base station for each hour. According to the figures we can observe that the traffic at the base stations is increasing with time. It means the traffic demand is growing continuously. In addition, to understand the trend of the traffic for the 24 hour and the weekly trend the data of each traffic group base station is extracted:

1. **For traffic of 24 hour:** The data between 2017-11-19 00:00:00 and 2017-11-20 00:00:00 has been extracted for all three group's base station.
2. **For one week:** the data between 2017-11-19 00:00:00 and 2017-11-25 00:00:00 is selected for visualization.

The traffic pattern for both the conditions is demonstrated in Fig. 6. Fig. 6(A) 24-hour data is given and in Fig. 6(B) one-week data is visualized. In both the diagrams the X axis contains the time and Y axis includes the traffic per hour. Based on the visual pattern observations the following facts are concluded.

A. Behavior of High Traffic Base Station:

First according to the traffic pattern of 24 hour, we can see:

a. The traffic between hour 00 and hour 03, remains very few or no traffic.
b. Next, after hour 03 it starts rising and remains below 200 till hour 15.
c. After hour 15traffic again starts rising and remains increasing till hour 20. At hour 20 it becomes in peak.
d. Finally, between hour 20 and hour 00, the traffic slowly decreases and becomes nearly to low.

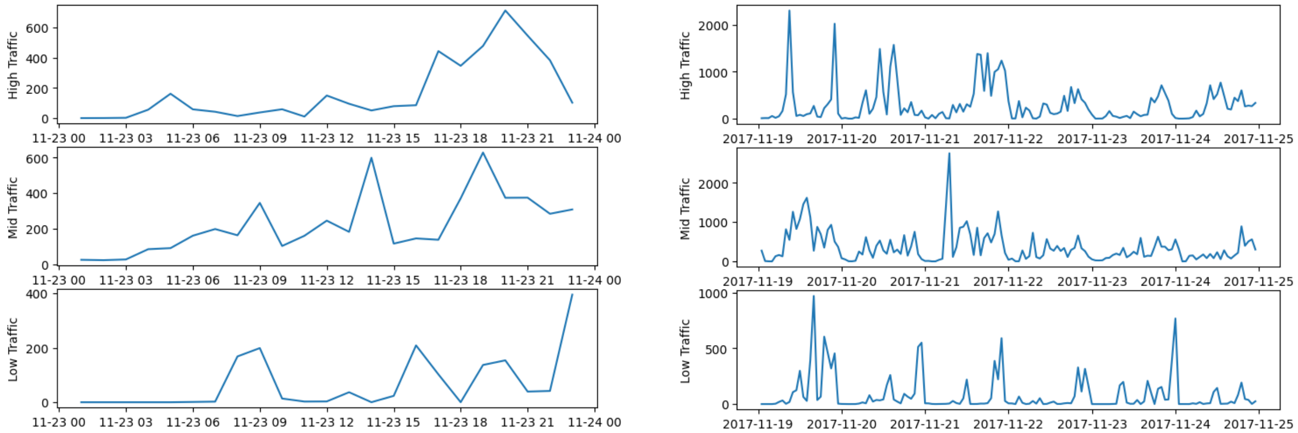
On the other hand, when we are talking about the weekly traffic pattern, then we can see:

a. However, the traffic shows a cyclic pattern throughout the week. Additionally, reducing day by day with the weekdays.
b. The selected data basically starts with the Sunday and the data is visualized till Saturday.
c. First two days (Sunday and Monday) it shows high traffic. The traffic shows 2000 as peak value.
d. Then for the next two days, Tuesday and Wednesday, the traffic is below then first two days but higher than the last three days. Here the peak values remain near about 1500.
e. Additionally, for the last three days (Thursday, Friday, and Saturday) the traffic is below then first four days. This traffic shows a peak near about 800 units.

Therefore, the high traffic group base stations are following a repetitive pattern. Means after each 24 hour and after each end of week again the same traffic pattern is repeated.

B. Behavior of Mid Traffic Base Station

The behavior of the base station traffic is different from each other. First, we start with the 24-hour traffic, which describes the following insights:



(A) (B)

Fig. 6. shows the traffic trends for (A) 24-hour period and (B) for one week time period

a. The traffic is increasing continuously in a regular manner. But it shows the lowest traffic between 00 hour and 03 hour.
b. Next, after 03 hour the traffic is growing continuously up to 09 hour and being at a peak which is near about 380.
c. After peak a sudden drop in pattern and then starts rising to get a new peak at hour 02. Next a similar kind of peak value is observed at hour 19 hour.

On the other hand, the weekly traffic pattern is also completely different from high traffic group base station. But we can divide the traffic in two parts:

a. The first four days (Sunday to Wednesday) show the similarity in traffic pattern and having high volume of traffic.
b. Last three days (Thursday to Saturday) the low traffic is found as compared to first four days.

Finally, the traffic pattern follows a cyclic pattern which is increasing and decreasing suddenly.Additionally, shows an increasing trend throughout the day.

C. Behavior of Low Traffic Base Station

The low traffic group base station shows a completely different traffic pattern as compared to the previous two given patterns. First, we are providing the insights of 24-hour traffic pattern:

a. Traffic at the base station between hour 00 and hour 07 remains near about 0 or very fewer.
b. Between hour 07 and 10 it increases and then becomes very fewer till hour 15.
c. Then it shows an odd pattern and increases but remains below 200 units.
d. Finally, it shows a sudden peak of 400-unit traffic between hour 22 and 00. Then shows a sudden down in pattern.

Finally, in terms of weekly traffic the traffic pattern remains consistent and low throughout the week but shows the cyclic pattern in 24-hour traffic conditions.

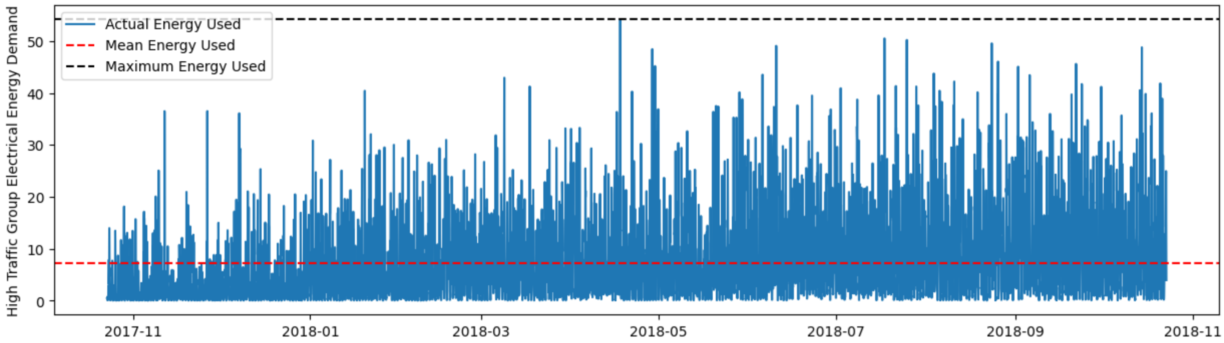
III. UNDERSTANDING ENERGY DEMAND OF BASE STATIONS

To smoothly execute smart city services, electrical energy plays an essential role [12]. Among different large scale electrical energy consumers in a smart city the cellular communication infrastructure is one of the crucial consumers [13]. In addition, to improve and deliver high quality communication-based services it is essential to deploy more and more cellular base stations. The increasing number of cellular base stations is also increasing the load on electricity generation and supply infrastructure [14]. Therefore, better utilization of electricity is required. In this presented work, the ultimate aim is to know the electricity demand of the base stations. Additionally, preserve the wastage of energy by using a proactive approach. In this paper, the electricity consumption pattern is tried to measure.

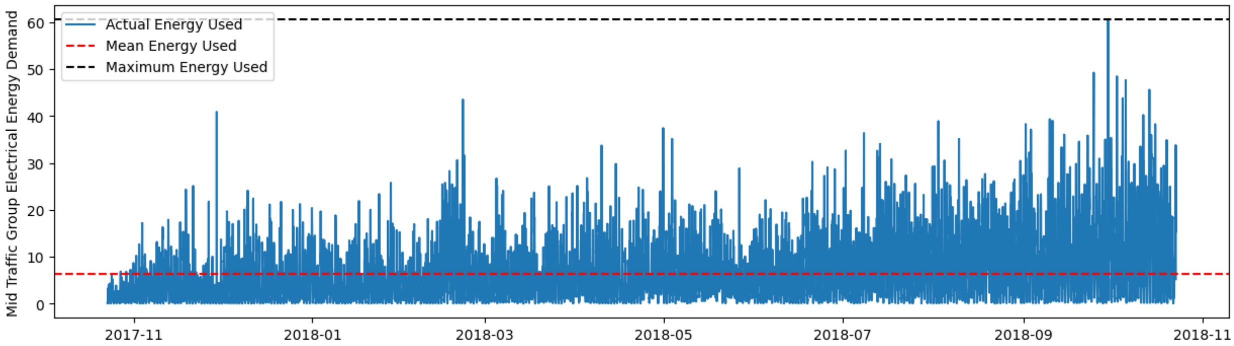
But the issue is the dataset does not contain the electricity demand property. Therefore, in this presented work it is assumed that the electricity demand E_d and traffic T_r has the following property:

$$E_d \propto T_r \qquad (2)$$

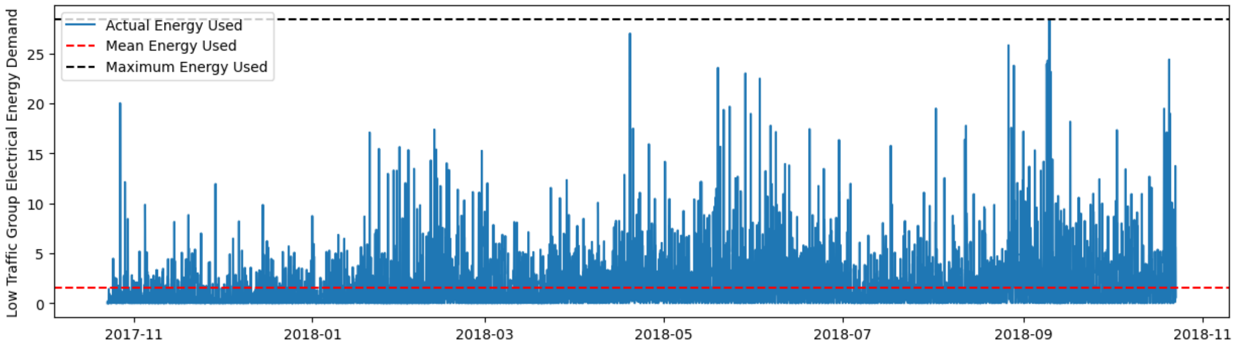
Using this relationship, we assumed that all the base stations are prepared with similar capability to serve maximum traffic demand. In this dataset, the maximum traffic per hour is 10282.96. Then, we assumed that the base stations could serve 11000 unit traffic. Let suppose that to serve the 11000 unit traffic per hour the base station requires 100 units of electricity. Then to serve 1 unit traffic the required energy is $\frac{1}{110}$ or 0.0091 unit of electricity required.



(A)



(B)



(C)

Fig. 7. Formulated Energy utilization of the selected base stations which are belongs to (A) High Traffic Group (B) Mid Traffic Group and (C) Low Traffic Group

Based on the assumptions made the actual power utilization of the selected base stations are measured and visualized in figure 7. In this diagram three figures are given, where figure 7(A) shows the actual, mean, and maximum electricity utilization of the high traffic group base station. In figure 7(B) the mid traffic group and in figure 7(C) low traffic group base station is visualized. Based on the visual analysis, we can see the mean energy utilization per hour for each base station is very fewer and below 10 units. Additionally, the maximum peak is demonstrated at 55 units of energy consumption. On the other hand, we can see in figure 7(B) the mean energy consumption per hour is low as compared to high traffic group, which is also below 10 units, but the maximum energy used is higher than the higher traffic group. Finally, the energy utilization of low traffic base stations is less than both the other scenarios in both the conditions mean and maximum. Further, the section discusses the obtained results of the conducted study.

IV. PROBLEM STATEMENT AND FORMULATION

Based on the experimental analysis it is found that the mean energy consumption of base stations is clearly indicating the traffic groups. Fig. 8 shows the mean energy utilization of three selected base stations. In this diagram, X axis shows the group type in terms of high, mid, and low. Additionally, the Y axis shows the mean energy used by the different traffic group base stations. The mean energy utilization is given here for a per

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hour basis. According to the mean values we can say, if the base station is running at their full capacity all the time.

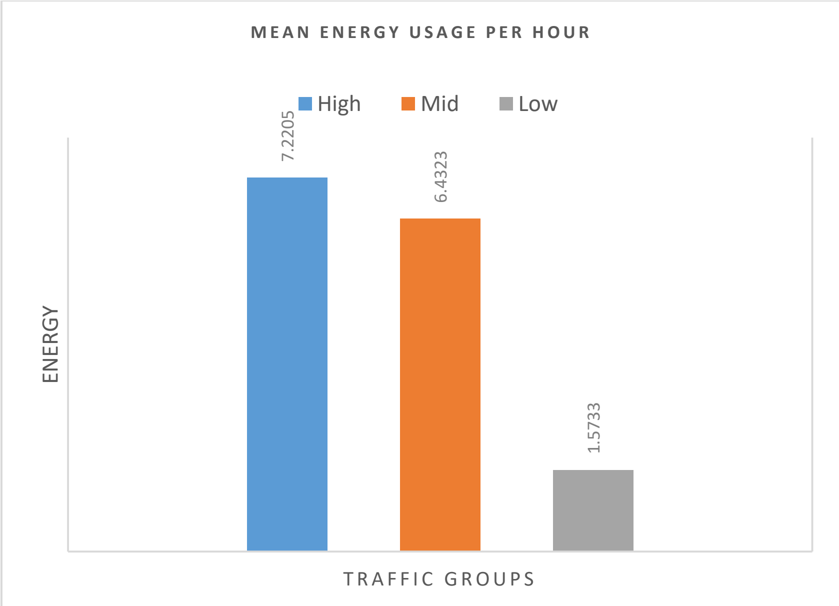

Fig. 8. Mean Energy Utilization

Then a significant amount of energy is being wasted every hour. On the other hand, the maximum energy utilized for all the three considered base stations is given in Fig. 9. In this diagram, X axis contains the traffic groups and Y axis includes the maximum energy used in an hour based on a complete year traffic condition.

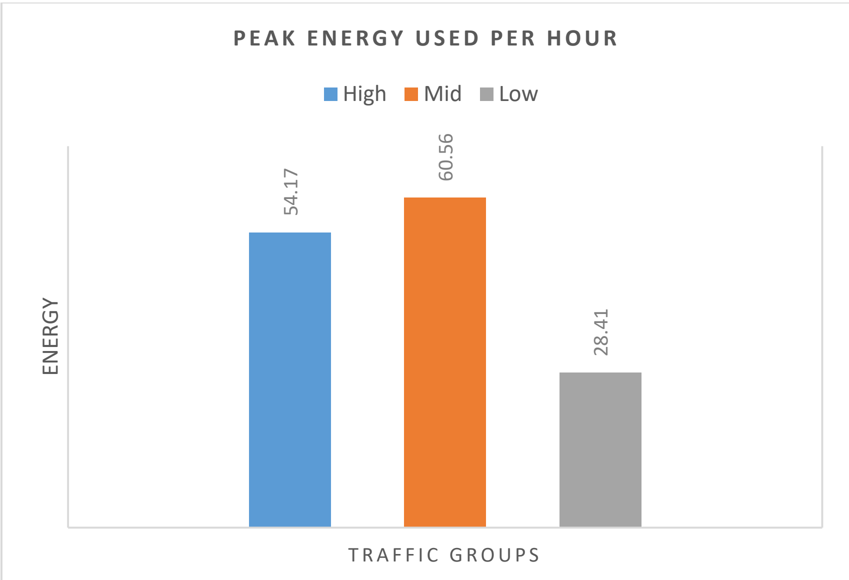

Fig. 9. Peak energy used

Based on the given results, we can say the maximum possible traffic cannot depend on the traffic group type. Next, we are trying to measure the total amount of energy wastage in both the conditions:

1. When all base stations are running on maximum possible capacity
2. When the base station running on the maximum or peak energy used

Fig. 10 includes a comparative wastage of energy by operating the basis stations according to the above given both the scenarios. Based on the conducted theoretical study it is found that a large amount of electrical energy is being wasted due to the dynamic nature of traffic demand. To deal with this problem, it is required to develop a traffic load aware power scheduling system for base stations. That can help to minimize energy wastage.

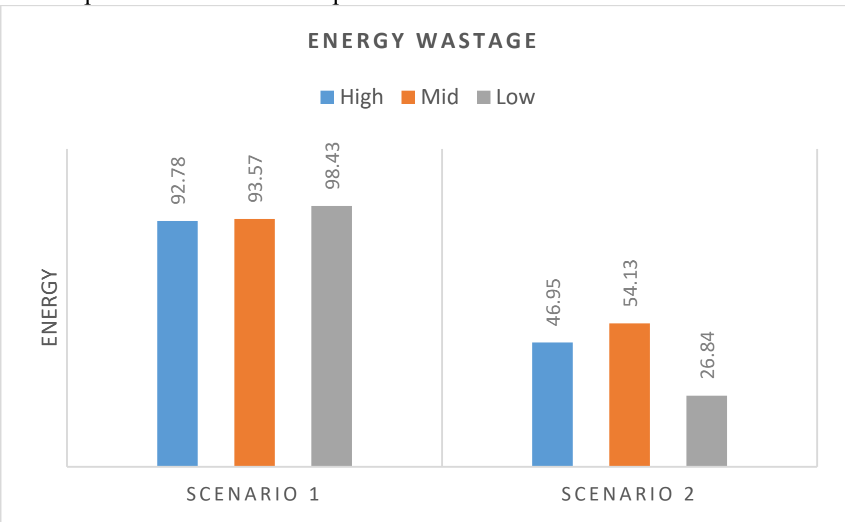

Fig. 10. Measured Energy wastage

V. CONCLUSION

The main aim of this paper is to discuss the cellular base station traffic pattern. Additionally, approximating the possible energy demand, actual utilization, and the amount of wastage. In this context, a dataset which contains hourly traffic data of base stations has been considered additionally a detailed exploration has been done. The dataset has been preprocessed and based on the total traffic load in a year the base stations are grouped. There are three groups are prepared based on the traffic behavior i.e. High, Mid and Low traffic groups. Additionally, based on the groups, three base stations have been selected to represent each group. Using the selected base stations the traffic patterns have been analyzed and then the energy requirements of each traffic group base station have been measured. Based on the actual energy utilization analysis we found a significant amount of energy i.e. more than 90% of energy got wasted when the base station is become ideal.

Finally based on the experimental analysis and the facts uncovered. The following key factors are needed to incorporate for designing an effective energy management system for base stations:

1. The traffic and energy utilization behavior of all the traffic group base stations are different from each other. Therefore, it is required to consider the behavioral differences when designing the energy saving system.
2. The peak traffic load of the traffic groups, more specific mid and high can be different according to the behavior.
3. The traffic behavior of the different traffic groups also varies in different period of time in the day and also varying with the days of the week.

Thus, soon an energy scheduling technique is proposed which incorporates the concluded insights as given above.

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