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Improving Energy Efficiency of 5G Radio Access Network

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ABSTRACT : As evolution of green technology increases, the energy efficiency in wireless networks has become a major focus. 5G networks supports large number of devices and requires high data rates, needing much energy consumption. The need to efficiently manage this energy consumption using machine learning is a major drive for this research. A 5G production dataset was cleaned, normalized and analyzed. Correlation investigation results shows that the highest correlation value of 0.78 exists between the reference signal received power (RSRP) and the reference signal received power of the neighbouring cells (nrxRSRP). A Dynamic Power Control algorithm was formulated and validated. Using the formulated Dynamic Power Control algorithm, the transmission power was seen to reduce from an absolute value of 91.7dBm to an absolute value of 65dBm, which improved on the energy efficiency of 5G network from $4.57 * 10^{11}$ Mbps/Watts to $4.45 * 10^{10}$ Mbps/Watts.

KEYWORDS: *5G, artificial intelligence, energy efficiency, improve, machine learning.*

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I. INTRODUCTION

Energy efficiency is the use of less energy to perform the same task or produce the same result. It can be described as the ratio between the total number of packets received at the destination node (i.e. the base station, in the case of collection protocols) and the total energy spent by the network to deliver these packets [1]. 73% of the energy of participating operators is consumed in the radio access network (RAN). The network core (13%), owned data centers (9%) and other operations (5%) account for the rest. In digital wireless networks, the system spectral efficiency or area spectral efficiency is typically measured in (bit/s)/Hz per unit area, in (bit/s)/Hz per cell, or in (bit/s)/Hz per site. Cellular technologies have seen gradual evolution from 1st to 5th generation (5G) for meeting demands in terms of bandwidth, throughput, latency and jitter [2].

Furthermore, each generation gave rise to energy consumption due to the addition of hardware to support applications and requirements. The need to support high data rates and a large number of devices are making these networks hungrier for energy. Until the 4th generation of mobile communication standard, the focus was to deliver high data rate. Over the past years, technologies such as the Internet of things (IoT) have resulted in billions of connected devices and the generation of an enormous volume of data. It was expected that the traffic volume will increase exponentially and will become 1000 folds by 2020. Also, the number of connected devices will continue to increase exponentially. It was expected that there will be approximately 50 billion devices by 2021[3]. In mobile networks, 80% of the total energy of cellular networks is consumed by base stations and has pivotal importance for energy efficiency improvements [4]. For instance, to improve the coverage and meet capacity requirements, a large number of small cells will be deployed. Small cells make the network denser, which leads to more energy consumption. According to the small cell forum, in 2024, all 4G small cells will be replaced by 5G small cells, reaching 13.1 million installations in 2025 [5].

II. METHODOLOGY

The 5G production dataset of [6] was used in the formulation, analysis and validation of the dynamic power control (DPC) algorithm for improved energy efficiency on the radio access network of 5G network. The Python programming language and 5G toolbox of MATLAB were used in the research work.
The 5G production dataset, which came in thirty-five (35) different subsets were merged together. The dataset was then cleaned by the removal of outliers, removal of inconsistent data points, encoding of non-numeric data points and descriptively renaming of the columns (features) using Pandas, the Python library used for working with datasets. The statistical distribution of each of the features were explored during the exploratory analysis by checking the minimum value, the maximum value, the mean, the standard deviation, the variance, the quartiles and the median points. The Matplotlib was used for the data visualization of the statistical distribution of these features. The visual plots were then used to determine the features of the dataset that needed to be normalized and they were normalized using the Scikit-learn. The variables that were not properly distributed were further investigated upon during the exploratory analysis.

After the normalization of the features needing normalization, the dataset was ready. The authors in [7] used the significance indicator to determine the key features of the production dataset needed to improve energy efficiency of a 5G network and they further used the Pearson correlation coefficient to show that the highest correlation exists between reference signal received power (RSRP) and the reference signal received power of the neighbouring cells.

Authors in [8], showed that for better performance and to avoid over-fitting, the hyper-parameters (Number of estimators and maximum depth of gradient descent) should be determined and set before the training and the testing/validation of the dataset. The dataset was then trained with 70% and tested/validated with 30% of the data. Table 1 is the raw sample of the 5G production dataset indicating its features, while table 2 shows the Python data analysis library used.

Table 1: Raw sample of the 5G Production Dataset.

	Longitude	Latitude	Speed	Operatorname	CellID	NetworkMode	RSRP	RSRQ	SNR	CQI	RSSI	DL_bitrate	UL_bitrate	State	NODEHEX	LACHEX	RAWCELLID	NrxRSRP	NRxRSRQ
0	-8.39486	51.88624	0	B	11	5G	-97	-12	10	13	-85.5992	141	44	D	A4DF	9CBA	10805003	-103	-14
1	-8.39486	51.88624	0	B	11	5G	-94	-13	8	11	-85.5992	0	7	D	A4DF	9CBA	10805003	-95	-204
2	-8.39272	51.88679	0	B	11	5G	-94	-13	8	11	-85.5992	0	7	D	A4DF	9CBA	10805003	-95	-204

3	-8.39272	51.88679	0	B	11	5G	-94	-13	8	11	-85.5992	53	8	D	A4DF	9CBA	10805003	-95	-204
4	-8.39272	51.88679	0	B	11	5G	-96	-13	4	11	-85.5992	0	0	I	A4DF	9CBA	10805003	-103	-19

Table 2: Python Data Analysis Library.

Python Library	Used for
Pandas	Data Frame Manipulation
Numpy	Mathematical Operations especially Matrix Arrays
Matplotlib	Data Visualization
Seaborn	Advanced Visualization and Plots
Scikit-learn	Data Normalization and Algorithm Building

One way to improve the energy efficiency of a 5G network on the radio access network is to optimize the transmission power of base stations based on traffic demand. The Dynamic Power Control (DPC) algorithm, an algorithm for controlling the transmission power and improving the energy efficiency of a 5G network which dynamically adjusts the transmission power of base stations to meet the Quality of Service (QoS) requirements while minimizing energy consumption was formulated and validated to achieve this. Its main feature is that it makes use of the absolute difference of the transmission power of the users in the access network.

The algorithm iteratively adjusts the transmission power of users based on the difference between the current signal to noise ratio (SNR) and the target SNR. The beta parameter controls the rate of power adjustment. The iteration runs for a fixed number of iterations to converge the transmission power levels.

The formulated Dynamic Power Control algorithm was simulated in the flowchart as shown in figure 1 using the MATLAB program. Table 3.3 shows the sample of the trained dataset showing the significant variables used in the MATLAB simulation.

Table 3.3: Trained sample dataset for the DPC Algorithm formulation.

	SN	Speed	ref_sig_power	ref_sig_qual	…
1	0	31	-98	-15	
2	1	31	-98	-15	
3	2	31	-94	-15	
4	3	31	-94	-15	
5	4	31	-91	-13	
6	5	31	-91	-13	

	SN	Speed	ref_sig_power	ref_sig_qual	...
7	6	31	-91	-13	
8	7	31	-91	-13	
9	8	31	-91	-12	
10	9	31	-92	-14	
11	10	31	-92	-14	
12	11	31	-91	-11	
13	12	31	-91	-11	
14	13	31	-91	-12	
15	14	31	-91	-12	
16	15	31	-92	-14	
17	16	31	-91	-13	
18	17	31	-91	-11	
19	18	31	-91	-11	
20	19	31	-91	-15	
21	20	31	-91	-15	
22	21	31	-92	-13	
23	22	31	-92	-13	
24	23	31	-92	-15	
25	24	31	-92	-15	
26	25	31	-91	-15	

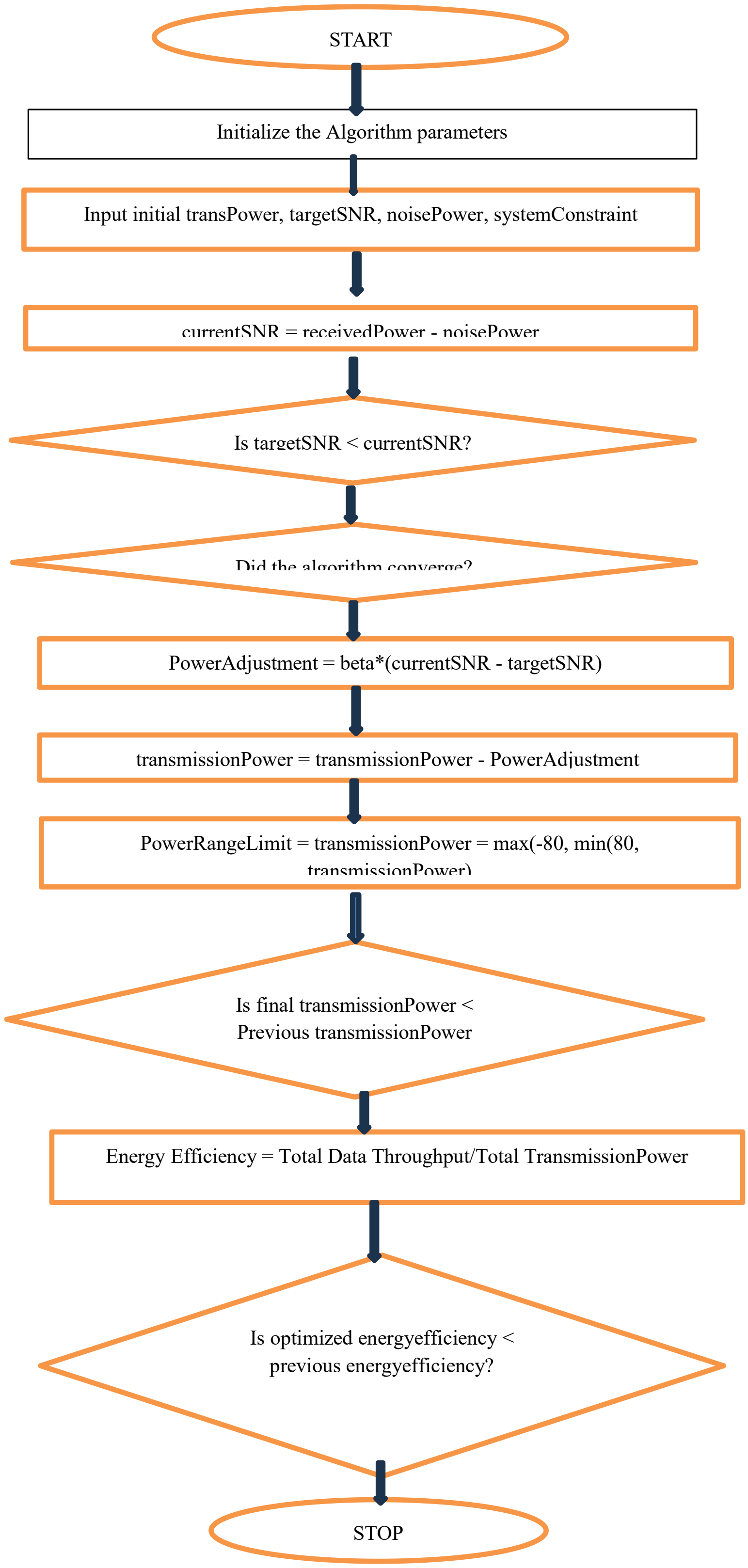

Fig. 1: Formulated and Validated Dynamic Power Control (DPC) Algorithm flowchart

Energy efficiency, being a measure of how effectively an energy source is converted into useful output. When comparing systems, processes or devices, a lower value of energy consumption for the same or better performance indicates that the system is more energy efficient.

III. RESULTS

The Dynamic Power Control results showed that the previous transmission power of absolute value 91.7dBm was greatly improved to an absolute value of 65dBm. This result, when validated with the known and established results of reference signal received power (RSRP) values of -44dbm (good) to -140dbm (bad), proved that there is great improvement, which after calculating the current (final) energy efficiency and the previous energy efficiency based on the transmission power, it was found that the current (final) energy efficiency is 44492163732.1554 Mbps/Watts ($0.4449*10^{11}$ Mbps/Watts), while the previous energy efficiency is 457440856550.6025 Mbps/Watts ($4.5744*10^{11}$ Mbps/Watts).

Comparing both energy efficiencies, which represents the amount of data transmitted per unit of energy consumed in the system. The lower (current) energy consumption value of $0.4449*10^{11}$ Mbps/Watts indicates a more efficient use of energy resources, leading to reduced environmental impact and cost savings. This is as shown in the bar chart of Fig.2.

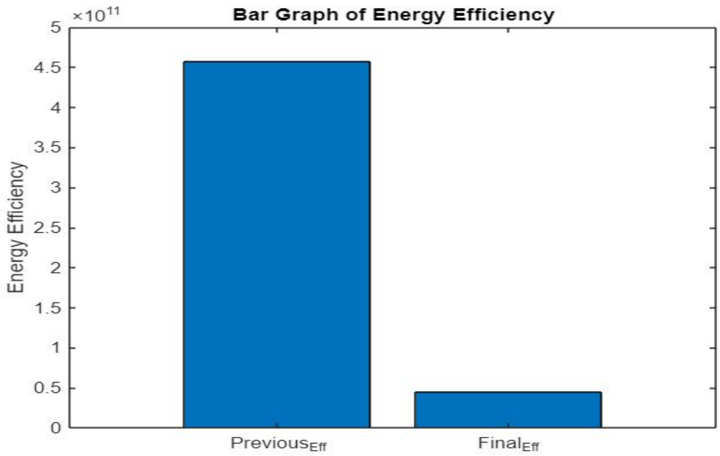

Fig.2: Comparison bar chart for Improved Energy Efficiency.

IV. CONCLUSION

This work sets to answer the question of how to improve the energy efficiency of a 5G network using machine learning. From the results obtained, using the Python programming language, it was found that there was very strong correlation amongst the best features determined from the 5G production dataset during the exploratory analysis using significance indicator. Using the MATLAB simulation 5G toolbox, and employing the Dynamic Power Control algorithm, the transmission power was reduced from an absolute value of 91.7dBm to an absolute value of 65dBm, which improved on the energy efficiency of 5G network from $4.57 * 10^{11}$ Mbps/Watts to $4.45 * 10^{10}$ Mbps/Watts. This lower energy consumption indicates improved or more efficient use of the energy resources.

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