5G-Energy Consumption Modelling

A Residual LightGBM Predictor for Energy Consumption Prediction

Presented by: Licheng Zheng
musicsirme@gmail.com
Ph.D Candidate, ETS, University of Quebec
Montreal, Canada

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Problem Statement

Leverage ML/AI to predict the energy consumption of base stations

The dataset provided for this competition was three comprehensive collections of base station basic information cell level data and Energy consumption

The provided data had 92629 training items and 26139 test items. Each item contains the essential information including:

1. Base Station Basic Information:
   Base Station ID, Cell Name, RUtype, Mode, Frequency, Bandwidth, Antennas and TXpower
2. Cell Level Data:
   Time, Base Station ID, Cell Name, load and ESMode1-6
3. Energy Consumption:
   Time, Base Station ID and Energy Consumption (training set only)

The Task - predict the Energy Consumed during some specific hours

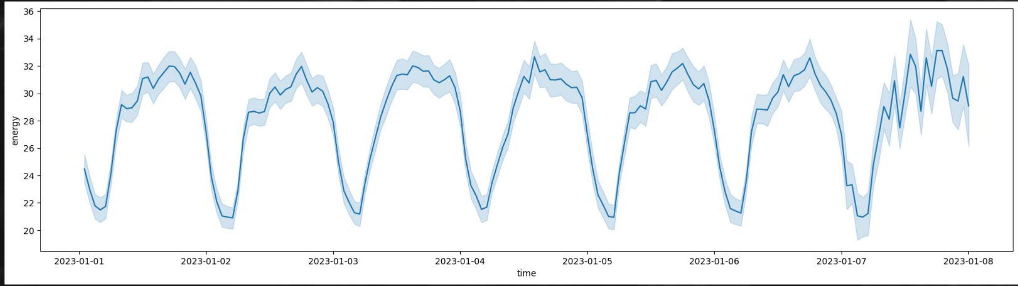
Evaluate - weighted mean absolute percentage error (WMAPE) scores

Dataset and EDA

Cell Level Data:

Time	BS	CellName	load	ESMode1	ESMode2	ESMode3	ESMode4	ESMode5	ESMode6
1/1/23 1:00	B_0	Cell0	0.48793617	0	0	0	0	0	0
1/1/23 1:00	B_105	Cell0	0.0503	0	0	0	0	0	0
1/1/23 1:00	B_105	Cell1	0.01674	0	0	0	0	0	0
1/2/23 0:00	B_105	Cell0	0.07884	0	0	0	0	0	0
1/2/23 0:00	B_105	Cell1	0.02141	0	0	0	0	0	0
1/2/23 0:00	B_105	Cell2	0.04605769	0	0	0	0	0	0
1/2/23 0:00	B_105	Cell3	0.04680769	0	0	0	0	0	0

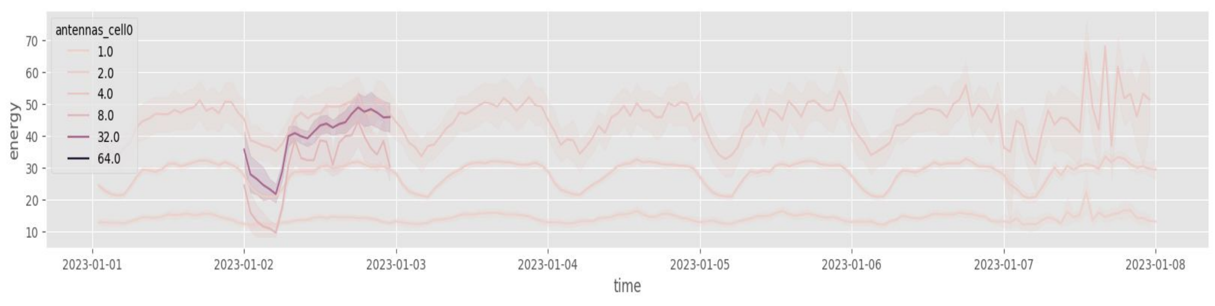
Period Energy:

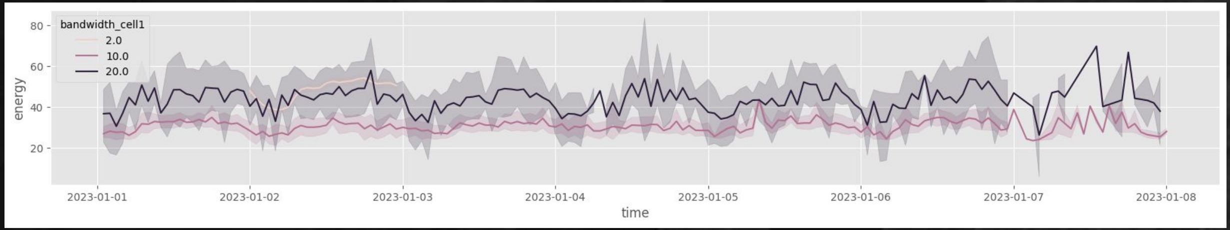


- The varying number of cells for each base station at different hours poses a challenge for Deep Neural Networks (DNN). This is because DNN requires a consistent input shape.
- The energy consumption of a base station exhibits periodic patterns with a 24-hour cycle. This observation led me to consider that feature data and energy consumption at the same hours of the day might be a valuable feature.

Dataset and EDA

Noise:





The energy data exhibits noise, which can have a negative impact on the decision trees algorithms like LightGBM.

Algorithms based on decision tree are iterative, and they adjust sample weights based on predictions from previous iterations. Consequently, as the iterations progress, errors tend to decrease, leading to a reduction in the model's bias [1].

However, this competition's data is marked by significant noise. Minimize the bias with noise may cause overfitting.

[1] Ke, G., Meng, Q., Finley, T., Wang, T., Chen, W., Ma, W., ... & Liu, T. Y. (2017). Lightgbm: A highly efficient gradient boosting decision tree. Advances in neural information processing systems, 30.

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Feature Engineering

Feature set 1:

we combine these three files based on timestamps and base station id. There are 11 basic features which are listed in the following table. This is a part of basic inputs.

features and cell	cell0	cell1	cell2	cell3
load	load_cell0	load_cell1	load_cell2	load_cell3
esmode1	esmode1_cell0	esmode1_cell1	esmode1_cell2	esmode1_cell3
esmode2	esmode2_cell0	esmode2_cell1	esmode2_cell2	esmode2_cell3
esmode3	esmode3_cell0	esmode3_cell1	esmode3_cell2	esmode3_cell3
esmode4	esmode4_cell0	esmode4_cell1	esmode4_cell2	esmode4_cell3
esmode5	esmode5_cell0	esmode5_cell1	esmode5_cell2	esmode5_cell3
esmode6	esmode6_cell0	esmode6_cell1	esmode6_cell2	esmode6_cell3
frequency	frequency_cell0	frequency_cell1	frequency_cell2	frequency_cell3
bandwidth	bandwidth_cell0	bandwidth_cell1	bandwidth_cell2	bandwidth_cell3
antennas	antennas_cell0	antennas_cell1	antennas_cell2	antennas_cell3
txpower	txpower_cell0	txpower_cell1	txpower_cell2	txpower_cell3

Feature set 2:

- Energy of past 5 days in the same hours(We will call this Previous Energy from now)
- Features of past 6 days in the same hours
- Difference on features of past 6 days in the same hours
- Percentage on features of past 6 days(We will call this Percentage of Features from now)

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Feature Engineering

Feature set 3:

- Difference of Features
- Product of Features
- This is the other part of basic inputs

NEW FEATURES CREATED

Type	Features
difference	load_minus_frequency load_minus_bandwidth load_minus_txpower frequency_minus_bandwidth frequency_minus_antennas frequency_minus_txpower bandwidth_minus_antennas bandwidth_minus_txpower antennas_minus_txpower
product	load_product_frequency load_product_bandwidth load_product_txpower frequency_product_bandwidth frequency_product_antennas frequency_product_txpower bandwidth_product_antennas bandwidth_product_txpower antennas_product_txpower

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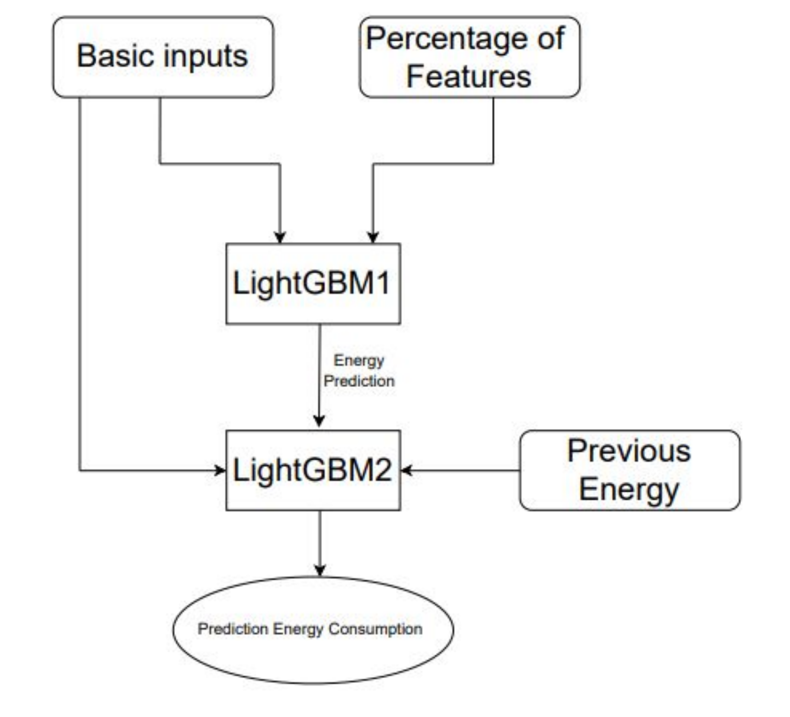
Model

Residual LightGBM:

- Two LightGBM structures are implemented: LightGBM1 and LightGBM2
- The Inputs of LightGBM1 are: Basic inputs and Percentage of Features
- The Inputs of LightGBM2 are: Basic inputs, Energy Prediction of LightGBM1 and Previous Energy.

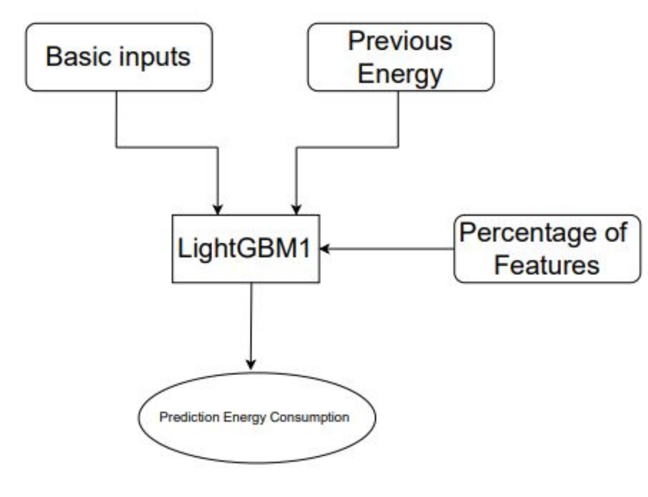
Residual LightGBM use the prediction as input. Because the basic inputs are used as input twice, it can alleviate the impact of noise.

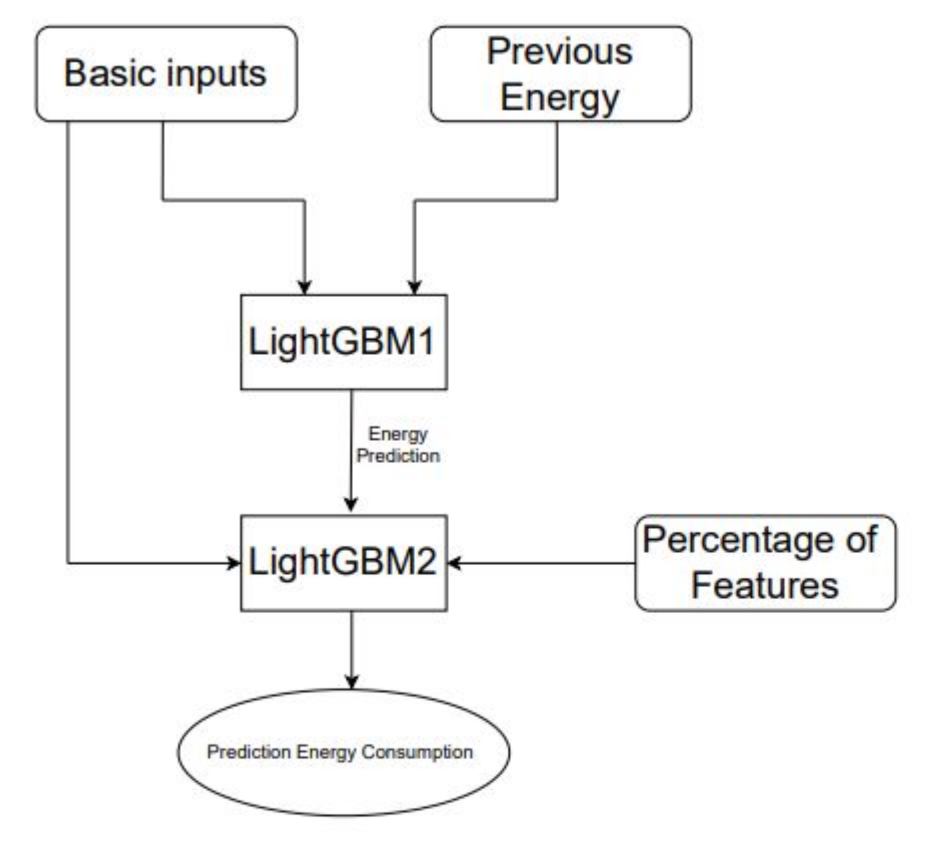


Baseline:

Baseline:

- Other shape of Residual LightGBM
- LightGBM





Submission:

Submission Scores of different Features:

In order to compare the performance, we use LightGBM to evaluate the efficiency of different features.

features	Public Scores	Private Scores
Basic features only	0.124709515	0.123136091
Differences + Basic features	0.113376462	0.111411138
Product + Basic features	0.118879751	0.117040871
Percentages of Features + Basic features	0.111652422	0.109514682
Previous Energy + Basic features	0.110787858	0.109594089

Submission Scores of different Models:

Structure	Public Scores	Private Scores
Residual LightGBM	0.093204536	0.092276470
Residual LightGBM2	0.101277934	0.100985862
LightGBM	0.105140196	0.104014936

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Conclusion and Future works:

Conclusion:
In this competition, we proposed a Residual LightGBM to solve the noise problem. We also provide some data processing and feature engineering. Finally, we got 0.093 on Public Scores and 0.092 on Private Scores.

Future Works:

- RUType and Mode are not used as our inputs. Because they cannot increase scores. In the future, we will explore more on how to use these two features.

- Deeper Residual LightGBM may helpful.


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Q & A