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Research on an AI-Based Cloud Platform for 5G Base Station Energy Consumption Supervision

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Abstract. This paper addresses the issue of energy consumption management in 5G base stations and proposes a solution in the form of an AI-based energy supervision cloud platform. Leveraging cloud computing and artificial intelligence technologies, the platform enables real-time monitoring, intelligent analysis, and optimized control of 5G base station energy consumption. By analyzing the characteristics of 5G base station energy use and supervisory requirements, the overall architecture and key modules of the platform are designed. The platform employs deep learning for energy consumption prediction and anomaly detection, and integrates reinforcement learning to achieve energy-saving control. Experimental results indicate that the platform effectively reduces energy consumption in 5G base stations, improves energy utilization efficiency, and provides strong support for the green and sustainable development of 5G networks.

Keywords: 5G base station, energy consumption supervision, artificial intelligence, cloud platform

1. Introduction

Energy consumption by base station equipment accounts for up to 50% of the total energy usage in wireless networks [1]. With the rapid deployment and application of 5G networks, and given the characteristics of high-frequency bands and large-scale antenna arrays, the energy consumption of 5G base stations has imposed significant operational cost pressures and environmental burdens on operators. Therefore, effectively supervising and optimizing 5G base station energy consumption has become an urgent issue. Traditional energy management methods rely on a “one-size-fits-all” timed energy-saving approach. As user experience expectations rise, such methods no longer meet the complex demands of 5G network scenarios. The development of the Internet of Things (IoT), cloud computing, and artificial intelligence technologies provides new solutions for supervising 5G base station energy consumption. This study aims to design an AI-based cloud platform for 5G base station energy consumption supervision. By employing intelligent methods, the platform seeks to improve the efficiency of energy management, reduce base station energy consumption, lower operators’ operational costs, promote the green and sustainable development of 5G networks, support national strategic goals, and facilitate sustainable socio-economic development.

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2. Analysis of the current status of 5G base station energy consumption supervision

The energy consumption characteristics of 5G base stations are mainly reflected in the following aspects: First, the introduction of Massive MIMO (Multiple Input Multiple Output) large-scale antenna technology in 5G wireless networks [2] significantly increases base station power consumption. Second, the support for diverse service scenarios in 5G networks leads to substantial fluctuations in base station energy use. Third, the high deployment density of 5G base stations results in a large overall energy consumption scale. These characteristics pose significant challenges to the management of 5G base station energy consumption. The main issues in energy management include: First, lack of real-time and accurate energy monitoring methods; Second, difficulty in accurately predicting changes in base station energy consumption; Third, inability to achieve intelligent energy optimization control. Therefore, it is imperative to build a comprehensive energy supervision platform capable of real-time monitoring, intelligent analysis, and optimized control.

3. Capability framework of the AI-based 5G base station energy supervision cloud platform

The construction of an AI-based 5G base station energy supervision platform is a highly complex project, encompassing an end-to-end process from data collection, data processing, AI analysis and prediction, to visualization and energy-saving strategy formulation. The platform is built on a domestically produced computing infrastructure, iteratively optimizing algorithms based on collected data to establish a comprehensive supervision system.

The energy supervision platform adopts a four-layer technical architecture, including the data collection layer, data processing layer, data analysis layer, and application layer. The data collection layer gathers operational data such as voltage, current, and server temperature from base stations via IoT gateway terminals. The data processing layer aggregates multi-source data to construct a data lake foundation. The data analysis layer, based on Huawei Ascend AI computing platform, employs deep learning algorithms such as LSTM for energy consumption prediction and anomaly detection, and integrates reinforcement learning to generate energy-saving strategies. The application layer provides functionalities including energy consumption visualization, strategy configuration, and system management. The overall technical architecture and the functions of each layer are shown in Figure 1.

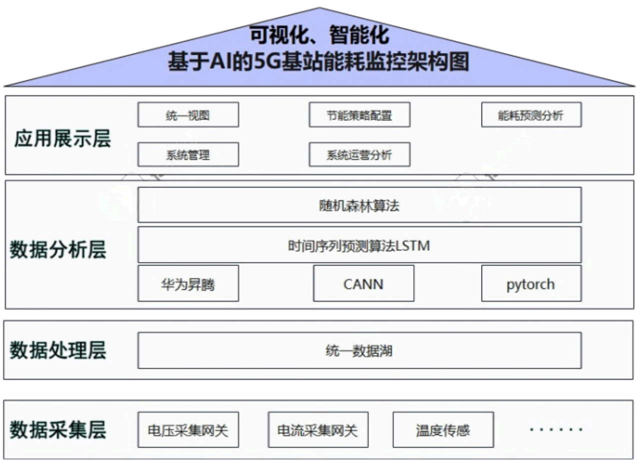

Figure 1. System architecture of the energy supervision platform

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4. Research on key platform technologies

The platform’s main functional modules include the data collection module, energy prediction and optimization control module, and visualization module. These modules work collaboratively to achieve comprehensive supervision and optimization of 5G base station energy consumption, thereby realizing energy saving and emission reduction.

4.1. Research on IoT data collection technology

Energy consumption data from base stations are collected in real time via edge gateways and sensors, supporting protocols such as MQTT and HTTP to ensure efficient and stable upload to the cloud platform. By deploying sensors and monitoring devices, real-time energy data of communication base stations—including electricity consumption, equipment power usage, and cooling system energy consumption—can be captured. This data provides an intuitive understanding of base station energy usage and forms the foundation for subsequent energy optimization [3].

4.2. Research on AI-based prediction technology

Long Short-Term Memory (LSTM) networks are a type of recurrent neural network (RNN) designed to handle long-term dependencies in time series data through recurrent memory units [4]. They address the gradient vanishing and exploding problems encountered by traditional RNNs when processing long sequences. By incorporating gating mechanisms, LSTM networks can effectively capture long-term dependencies, and have been widely applied in fields such as natural language processing, speech recognition, and time series forecasting.

In this platform, an LSTM neural network is employed for time series prediction, where the gating mechanism effectively captures long-term dependencies. The network structure consists of three stacked LSTM layers to enhance feature extraction capabilities.

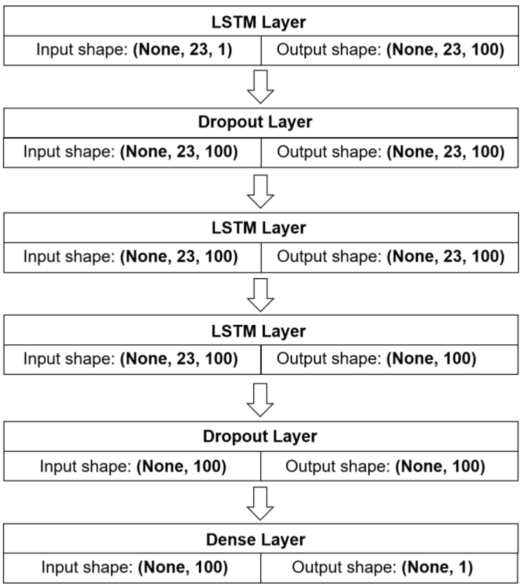

Figure 2. Three-layer LSTM network structure

For model training, electricity consumption data from a certain city, recorded for every hour from January 1, 2016, to January 1, 2018, totaling 17,520 time series data points, were used as the dataset.

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This dataset spans a long period and contains a large volume of data, providing substantial real-world value.

	A	B
1	日期	用电量/千瓦时
2	2016/1/1 0:00	13487
3	2016/1/1 1:00	13135
4	2016/1/1 2:00	12912
5	2016/1/1 3:00	12685
6	2016/1/1 4:00	12631
7	2016/1/1 5:00	12667
8	2016/1/1 6:00	12937
9	2016/1/1 7:00	13297
10	2016/1/1 8:00	13635
11	2016/1/1 9:00	13828
12	2016/1/1 10:00	14232
13	2016/1/1 11:00	14528
14	2016/1/1 12:00	14626
15	2016/1/1 13:00	14568
16	2016/1/1 14:00	14284
17	2016/1/1 15:00	14106
18	2016/1/1 16:00	14064
19	2016/1/1 17:00	14350
20	2016/1/1 18:00	15307
21	2016/1/1 19:00	15594
22	2016/1/1 20:00	15595
23	2016/1/1 21:00	15473
24	2016/1/1 22:00	15280
25	2016/1/1 23:00	14833
26	2016/1/2 0:00	14338
27	2016/1/2 1:00	13966
28	2016/1/2 2:00	13751
29	2016/1/2 3:00	13642
30	2016/1/2 4:00	13668

Figure 3. Experimental dataset

In the LSTM model, the training and testing data are represented as XXX and YYY, where XXX consists of the first 23 data points and YYY is the 24th data point. The experimental data are hourly time series, and a sliding window of 24 hours (representing one full day's electricity consumption) is used. During training, the first 23 data points in the window serve as input to predict the 24th data point. By comparing the predicted value with the actual 24th data point, the prediction error (loss) is calculated, allowing the model parameters to be continuously optimized.

(4) Experimental Results and Analysis

The dataset was split into training and testing sets in an 8:2 ratio. After training for 300 epochs, the model converged. Since the LSTM task is a regression problem, both the Mean Squared Error (MSE) and Mean Absolute Error (MAE) indicators show satisfactory performance.

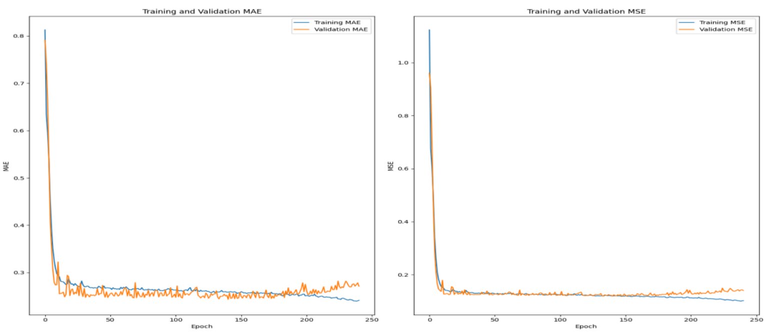

Figure 4. MSE and MAE Indicators

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For testing, a 100-hour period from 00:00 on October 1, 2017, to 04:00 on October 5, 2017, was selected. On October 1, electricity consumption was relatively high, peaking around 12:00 due to holiday-related factors such as intensive commercial activity, tourism, and family gatherings, which significantly increased energy demand. As shown in Figure 5, the predicted electricity consumption closely matches the actual values, with minimal prediction error.

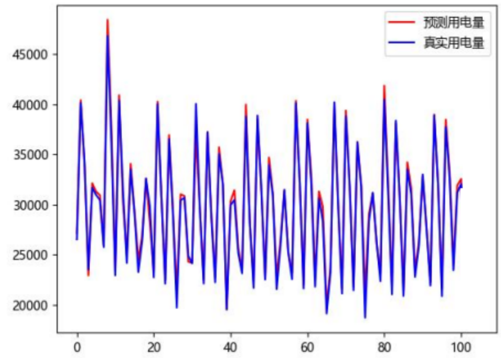

Figure 5. City electricity consumption prediction performance

Based on the prediction results, the platform dynamically adjusts the base station transmission power using a deep Q-learning algorithm. During periods of low electricity demand (troughs), the system reduces transmission power; during periods of high demand (peaks), it increases transmission power.

4.3. Research on modular technology of the application display layer

To achieve microservice-based deployment, the display layer adopts a cloud-native architecture combining Vue, Spring Cloud, and Kubernetes. The front end is built with Vue.js to construct a component-based user interface. The back end is based on the Spring Cloud microservice framework, decoupling each functional module so that each microservice is responsible for a specific business function. Service deployment leverages Kubernetes to enable containerized deployment, facilitating rapid deployment, high availability, and elastic scaling. The detailed system architecture is illustrated in Figure 6.

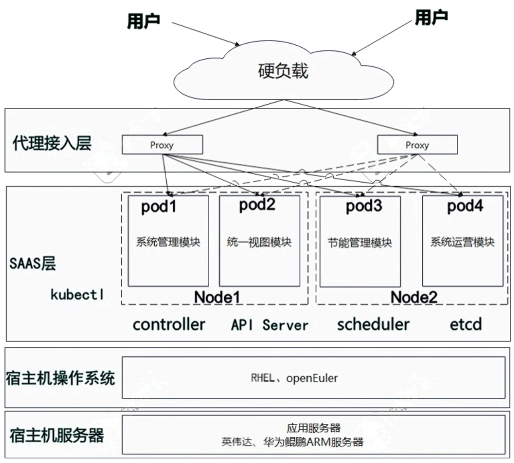

Figure 6. System architecture based on Vue + Spring Cloud + Kubernetes

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5. Research conclusions

This study designed an AI-based cloud platform for 5G base station energy supervision, effectively addressing key challenges in managing 5G base station energy consumption. During platform implementation, deep learning frameworks and Kubernetes container orchestration technologies were employed. The energy prediction model is based on the LSTM neural network, trained using historical energy consumption data, while the energy optimization algorithm utilizes deep Q-learning to intelligently adjust base station parameters. The platform is deployed in an OpenStack cloud environment, ensuring system scalability and reliability.

Through actual deployment and testing, the platform demonstrated excellent performance. The energy consumption prediction accuracy exceeded 92%, and the F1-score for anomaly detection reached 0.89. Regarding energy optimization, the platform reduced base station energy consumption by 15%-20%, significantly improving energy utilization efficiency. Compared with traditional energy management methods, this platform shows substantial improvements in prediction accuracy, optimization effectiveness, and response speed.

6. Summary and outlook

This study developed an AI-based cloud platform for 5G base station energy supervision, effectively addressing key issues in 5G base station energy management. By leveraging deep learning and reinforcement learning techniques, the platform achieves precise energy consumption prediction and intelligent optimization, supporting the construction of green and efficient 5G communication networks and promoting the sustainable development of a digital society [5]. Future research will focus on further enhancing the platform's intelligence, exploring additional energy-saving strategies, and laying the groundwork for energy management in 6G networks.

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