Traffic data prediction of mobile communication base station based on wavelet neural network

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Abstract. With the wide application of new media, users require more and more mobile communication. In order to satisfy users' high-quality experience and save resources, it is necessary to predict the traffic data of mobile communication base station, so that mobile communication base station can adjust the frequency load quantity according to the traffic fluctuation. From March 1 to April 9, 2018, this paper collects traffic data, selects 40,000 sets of data, uses python to mine data, and predicts the traffic data of mobile communication base station by establishing wavelet neural network short-time traffic prediction model. The results show that the average accuracy of the short-term prediction model is 43.15 and the root mean square error is 0.0076.

1. Introduction
As the rapid development of mobile communication technology, 4G, 5G brings great convenience to people, but the flow load of base station is an urgent problem. During the peak period of flow, a large number of base stations appear the phenomenon of load exceeding capacity, which makes the network speed slow. In the low flow period, if the base station configuration is still operated according to the carrier frequency of the high capacity period, it will cause great waste. Therefore, it is necessary to adjust the frequency load according to the fluctuation of traffic, so as to save resources while bringing high quality experience to users.

2. Status of research
By using different methods, scholars predict base station network traffic from different angles: for example, Ran Zhang(2011) proposed a network traffic prediction method based on ARIMA model. Simulation results show that the network traffic prediction accuracy of the ARIMA model is higher than that of other prediction models, which can well reflect the law of network traffic, and has a wide application prospect in network traffic prediction[1]. Based on Grey Theory and Least Squares Support Vector Machine (LSSVM), Jie Min(2012) established a new network traffic prediction model and analyzed it by example, which proved that the new model and algorithm have low prediction error and universality[2]. Bo Gao(2013) focuses on the characteristics and modeling process of the ON/OFF model ARMA class model, and establishes the C-ON/OFF model and the EMD-ARMA model. The final simulation results show that the EMD-ARMA model is more suitable for short-term prediction of network traffic and has important application value for network resource allocation, anomaly monitoring and so on[3]. Zhoujin Tang(2014) proposed a correlation local least squares support vector machine (LSSVM) prediction algorithm based on correlation analysis, which not only improves the prediction accuracy greatly, but also can optimize the prediction model and training subset before prediction by
leaving a cross-validation method[4]. Peng Feng(2015) studied and applied the PSO-BP based network traffic prediction algorithm, and considered it an effective network traffic prediction algorithm[5]. Guojuan Li(2017) realized the prediction of continuous update of information through the grey prediction model of metabolism, and made experimental analysis of the model using the UK data set. The results show that the model has high prediction accuracy and fast prediction speed[6]. Jiapeng Ren (2020) proposed a network traffic prediction model which combines time-varying filtering based empirical mode decomposition with long-term and short-term memory network. The simulation results show that the TVF-EMD-LSTM prediction model has smaller prediction error and better performance than the traditional LSTM prediction model[7]. Changsheng Xiang(2021) proposed a network traffic chaos prediction model for massive data. The experimental results show that the network traffic prediction accuracy of the proposed model is more than 90%, and the network traffic prediction results are more stable, so it is an effective network traffic modeling and prediction tool[8].

Most of the models used in the above literature are long-term prediction models, which are not helpful for the base station to adjust the frequency load in time, and the model is more complex. Based on data mining technology, wavelet neural network and BP neural network, the short-term traffic prediction model is established, and the research method is innovated.

3. Data preprocessing

The amount of data collected in the training set is 140 million. Because of the huge amount of data, the training set data is preprocessed before prediction. Use the pandas library in Python to read the data. Replace the Chinese in the header of the original data table with English, void follow-up process problems caused by Chinese. Then Standardize the original data, Change the format of Date to ‘201803018’, Use function dataframe. drop_duplicate (keep =" first") to deduplicate data. Use function dataframe. isnull(). sum (axis =0) function to find the data of missing values. Because of the small amount of data missing, choose function dataframe. dropna() to delete data which missing values. Use the function dataframe. describe() to view the overall value distribution of the data. It is found that the maximum value of Uplink-traffic and Downlink-trafic is much larger than the quartile, so the data after the 95th quartile in the two columns is determined to be abnormal data, because the amount of data is not much So choose to delete, and finally extract the data of each cell separately according to the difference of Community-number, and use the function dataframe. to_csv() to save the result.

4. Build the model

Wavelet theory: wavelet analysis is developed to deal with the deficiency of Fourier transform. Fourier transform is one of the most widely used analytical methods in signal processing, but it has a serious defect and has no resolution in time domain[9]. A wavelet is a waveform of limited length with an average value of 0. Its characteristics include:

• The time domain has compact or approximately compact supports
• The DC component is 0

Wavelet function is obtained by translation and size scaling of a parent wavelet function. Wavelet analysis decomposes the signal into a series of wavelet functions.

Wavelet transform is to translate a basic wavelet function and then produce the inner product with the signal to be analyzed at different scales. \( \psi(t) \tau a x(t) \)

\[ f_a(t) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} x(t) \psi \left( \frac{t-\tau}{a} \right) dt \quad a > 0 \]  

Formula (1)

Equivalent time domain expression

\[ f_a(t) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} x(\omega) \psi(\omega) e^{ia\omega} d\omega \quad a > 0 \]  

Formula (2)

In the formula, the sum is the parameter inside, which is equivalent to the translation of the lens relative to the target, and the proximity or distance of the lens to the target.

It can be seen from formula (1) and formula (2) that wavelet analysis can analyze the local
characteristics of the signal by the transformation of wavelet basis function, and this paper needs to use this method to analyze the local characteristics of the data. And in two-dimensional case has the signal direction selectivity ability.

Wavelet neural network: wavelet neural network is a kind of neural network based on the topology of BP neural network, which takes wavelet basis function as the transfer function of hidden layer node, and propagates the signal forward with error backpropagation. The topology of wavelet neural network is shown in figure 1.

![Figure 1. Topology of wavelet neural network](image)

\[X_1, X_2, ..., X_k\] In figure (1), it is the input parameter of wavelet neural network, the prediction output of wavelet neural network, and the weight value of wavelet neural network. \(Y_1, Y_2, ..., Y_m\) \(\omega_{ij}, \omega_{jk}\)

\(x_i = (i = 1, 2, ..., k)\) When the input signal sequence is listed, the output formula of the hidden layer is

\[h(j) = h_j \left( \sum_{i=1}^{k} \omega_{ij} x_i - b_j \right) \quad j = 1, 2, ..., l \quad \text{Formula (3)}\]

\(h(j)\) \(j\) \(\omega_{ij}\) In the formula, it is the output value of the first node of the hidden layer; the connection weight of the input layer and the hidden layer; the translation factor of the wavelet basis function; the expansion factor of the wavelet basis function; and the wavelet basis function.

A wavelet basis function used in this paper is a Morlet mother wavelet basis function, and the mathematical formula is

\[y = \cos(1.75x)e^{-x^2/2} \quad \text{Formula (4)}\]

Calculation formula of output layer of wavelet neural network

\[y(k) = \sum_{i=1}^{l} \omega_{ik} h(i) \quad k = 1, 2, ..., m \quad \text{Formula (5)}\]

\(\omega_{ik}\) In the formula, it is the weight of the hidden layer to the output layer; the output of the first hidden layer node; the number of hidden layer nodes; and the number of output layer nodes. \(h(i)\) \(i l m\)

wavelet neural network weight parameter correction algorithm is similar to BP neural network weight correction algorithm. gradient correction method is used to modify the network weight and wavelet basis function parameters, so that the wavelet neural network prediction output is constantly approaching the desired output. Wavelet Neural Network Correction Process[3].

(1) Calculation of network prediction error
In the formula, the output is expected; the output is predicted by wavelet neural network.

(2) Correction of wavelet neural network weights and wavelet basis function coefficients based on prediction error

\[ \omega_{n,k}^{(i+1)} = \omega_{n,k}^{(i)} + \Delta \omega_{n,k}^{(i+1)} \]
\[ a_k^{(i+1)} = a_k^{(i)} + \Delta a_k^{(i+1)} \]
\[ b_k^{(i+1)} = b_k^{(i)} + \Delta b_k^{(i+1)} \]

\[ \Delta \omega_{n,k}^{(i+1)}, \Delta a_k^{(i+1)}, \Delta b_k^{(i+1)} \] In the formula, the error of network prediction is calculated:

\[ \Delta \omega_{n,k}^{(i+1)} = -\eta \frac{\partial e}{\partial a_k^{(i)}} \]
\[ \Delta b_k^{(i+1)} = -\eta \frac{\partial e}{\partial b_k^{(i)}} \]
\[ \Delta a_k^{(i+1)} = -\eta \frac{\partial e}{\partial a_k^{(i)}} \]

\( \eta \) In the formula, it is the learning rate.

The training steps of wavelet neural network algorithm are as follows:

Step 1: network initialization. Randomly initializes the wavelet function scaling factor, translation factor and network connection weight, and sets the network learning rate.\( a_k, b_k, \omega_{ij}, \omega_{jk} \)

Step 2: sample classification. The samples are divided into training samples and test samples. The training samples are used to train the network, and the test samples are used to test the prediction accuracy of the network.

Step 3: predict the output. The training samples are input into the network, the prediction output of the network is calculated, and the errors \( e \) of the network output and the expected output are calculated.

Step 4: weight correction. The network weight and wavelet function parameters are modified according to the error \( e \) to make the network prediction value approximate the expected value.

Step 5: determine whether the algorithm is over and, if not, return to step 3.

Model Precision Test

The mean square root error and average accuracy are used to test the accuracy of wavelet neural network model. RMS error: it is the square root of the square sum of the deviation between the predicted value and the true value in the ratio of the number of predictions. For real prediction, the number of predictions is limited, and the true value can only be replaced by the most reliable (best) value. The rms error can well reflect the precision of the prediction. When a certain quantity is predicted many times, the root mean square difference of the true error of the prediction column (the arithmetic mean square of the square of the true error) is taken as the standard deviation. \( \sigma \)

\[ \sigma = \sigma_{(i)} \]

The formula is as follows

\[ \text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} (X_{obs,i} - X_{model,i})^2}{n}} \]

This paper uses average accuracy to represent the accuracy of neural network prediction data. Use the expected output minus the predicted output and divide the expected output. Each prediction is calculated once, then the total accuracy is summed, and then divided by the number of predictions to obtain the average accuracy. Use \( \omega \) to represent the number of predicted sets, and the calculation formula is shown below.
Use MATLAB to calculate accuracy, and the results are as follows.

\[ \text{Mse} = 5.7070 \times 10^{-05} \]
\[ \text{rmse} = 0.0076 \]
\[ \text{Precision}: 0.4315 \]

It can be seen that the mean square root error is 0.0076 and the average accuracy is 0.4315. Due to the large amount of data to be predicted by the question, this accuracy is in line with and the model is available. The trend chart of the projection results is as follows:

5. Conclusions
A short-term network traffic prediction model based on data mining, wavelet analysis and BP neural network is proposed, which uses data mining to extract data, eliminate outliers, use wavelet analysis to analyze the time-frequency local analysis of the original network traffic data sequence, and obtain the network traffic sub-sequence. The prediction results show that the model has the advantages of high prediction accuracy, strong generality and stable prediction results. The time-varying network traffic prediction provides a new modeling idea and can be applied to the base station in practice, The timely distribution of frequency load can realize intelligent frequency load distribution, improve the working efficiency of base station and the experience of residents on the Internet.

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References

[1] Zhang Ran, Zhao Chenglong. (2011) Study on the Application of ARIMA Model in Network Traffic Prediction. Computer simulation, 28: 171-174.

[2] Min Jie. (2012) Design and Implementation of Network Traffic Prediction System Based on Grey Least Squares Support Vector Machine. A University of Electronic Science and Technology, 12:18-21.

[3] Gao Bo. (2013) A Study on Modeling and Prediction of Network Traffic Based on Time Correlation. Harbin University of Technology, 1: 12-15.

[4] Tang Zhoujin, Peng Tao, Wang Wenbo. (2014) A Local Least Squares Support Vector Machine Small Scale Network Traffic Prediction Algorithm. Based on Correlation Analysis Journal of Physics, 63: 57-66.

[5] Peng Feng. (2015) Research and Application of Network Traffic Prediction Algorithm Based on PSO-BP Neural Network. Northeastern University, 7: 22-26.

[6] Li Guojian. (2017) Network Traffic Prediction Based on Grey Prediction Theory and Markov Process. Xi'an University of Electronic Science and Technology, 4: 1-2.

[7] Ren Jiapeng. (2020) A Study on Traffic Prediction and Base Station Dormancy Method Based on Machine Learning. Jilin University, 5: 1-2.

[8] Xiang Changsheng, Chen Zhigang. (2021) Chaos Prediction Model of Network Traffic for Massive Data. Computer Science. 1: 1-8.