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Wireless Communication Base Station Location Selection and Network Optimization Based on Neural Network Algorithm

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Abstract: Base station location selection and network optimization are critical to improving the performance of wireless communication networks in terms of latency reduction. To this end, the article proposes leveraging a convolutional neural network (CNN) to improve the accuracy of base station location selection and network latency reduction. The CNN method, based on a three-dimensional representation including signal strength data set, network topology data set, and transmission path data set, is used to select base station location and optimize the multihop relay network for latency reduction. The article presents a following method: location selection and network optimization for the wireless communication network. First, it collects the experimental data set of base station location selection and network optimization, and then uses the training data to train the CNN model to extract features. Once the training is done, the article further optimizes the network parameters and configurations, and ultimately obtains the optimal base station location and network configuration while minimizing network latency. As a result, simulation results indicate that the CNN model has remarkable performance in base station location selection, as well as in network optimization. In summary, the feature extraction and processing ability of CNN are powerful, enabling it to effectively capture factors leading to delay, hence improving the performance of base station location selection and network optimization. The article also demonstrates that the CNN model can be adjusted according to different environments and scenario settings through dynamic tuning.

1. Introduction

Recently, with the rapid development of wireless communication technology, the enhancement of wireless network performance is concerned with meeting the increasing communication demands. For wireless communication systems, the selection of base station location and network optimization are the most critical works which need to ensure network coverage, signal quality and network end to end latency reduction. Because of environmental conditions, network topology and increasing user needs, this has caused the traditional approaches to face shortcomings when it comes to achieving reliable base station location selection and network optimization.

To solve the shortcomings of existing methods, this article applies the Convolutional Neural Networks (CNN) to the research on the positioning of wireless communication base stations and the optimization of the network. CNN is widely used in image processing and sequence data processing. The powerful feature extraction and processing ability can help people to find a new way to solve the problem of wireless communication. By using the method of CNN, it can more accurately capture the cause of delay. After the optimization of network parameters and configuration, the network delay can be reduced, which can greatly improve the performance and user experience of wireless communication system.

The article initially describes the background and related work of wireless communication base station location selection and network optimization, and points out the shortcomings of traditional methods of base station location selection and network optimization, and the potential of the CNN method. The article then gave a detailed explanation of CNN and illustrated its role in wireless communication base station location selection and network optimization, as well as its advantages. After that, the contribution and future research directions of the article are summarized.

2. Related Work

Many people have studied the location selection of network base stations, and Bian Qiang proposed a base station location planning method based on an improved K-means algorithm in hilly environments. By establishing a mathematical model for selecting base station locations in hilly environments, he designed a base station location method based on the improved K-means algorithm and used the maximum coverage rate of the planned area as the evaluation index for the results of base station location [1]. Yang Fengyong proposed a base station positioning algorithm that combines mean shift algorithm and DBSCAN (Density-Based Spatial Clustering of Applications with Noise) clustering algorithm to solve the problem of reasonable location selection for base stations. This algorithm divides a large region into smaller sub regions and uses the mean shift algorithm to calculate the density extremum points of local service volume density in each sub region [2]. Song Juwei proposed to use wind turbines as base station locations based on the characteristics of the wind power plant industry and the high advantages of wind turbines themselves. He conducted research and application implementation on the feasibility of deploying base stations and antenna feedback systems in wind turbines, laying a solid foundation for the promotion and application of wireless private networks in the wind power industry, and assisting in the construction of smart grids [3]. Li Xuegang believed that wireless communication networks have the characteristics of being fast and efficient in transmitting information, and can transmit a large amount of information in a short period of time. While introducing the application and characteristics of communication base station towers, he also explores the relationship between the selection of communication base station towers and basic design based on their site selection requirements [4]. Zhang Lingzhi analyzed the coverage and site selection design of wireless communication network base stations, and deeply analyzed the inherent causes of network coverage, hoping to promote the rational development of network planning and optimization design work [5]. Lai C C proposed a density aware layout algorithm that maximizes the number of covered users while satisfying the constraint of the minimum data transmission rate for each user [6]. Yang J studied the relationship between base station antenna tilt and downlink network performance from the perspectives of coverage probability and Atomic Simulation Environment (ASE) [7]. Kishk M proposed a drone cellular network setup based on tethered drones [8]. Xiao Z formulated the problem as maximizing the achievable total rate for all users, subject to the minimum rate constraint for each user, the position constraint of the drone base station, and the constant modulus constraint of the beamforming vector [9]. Wang M reviewed the applications of transfer learning algorithms in different wireless communication fields, such as base station/access point switching, indoor wireless positioning, and wireless network intrusion detection [10]. These studies provide many methods for site selection of base stations, and this article can further investigate them through neural network algorithms.

3. Method

3.1 Problem Modeling

The article considered selecting wireless communication base stations in a city to optimize network coverage and performance. In this case, the goal of this article is to determine the optimal base station location within a given geographical area [11-12] to maximize signal coverage and meet user needs. Cities can be divided into discrete grid units, each representing a potential base station location. The influence of factors such as urban terrain, buildings, and vegetation on signal propagation can be considered. A signal coverage model is defined to establish the relationship between signal strength and distance through the path loss model, so that it can calculate the signal strength at each base station location and identify which areas have signal good enough to meet the user requirements [13-14]. Taking into account the user requirements, the minimum signal strength and the requirement for capacity are defined as the service quality indicators in this study. The user requirements can be met in every corner of the city, at the same time, the signal quality and the capacity have reached a certain level are the minimum requirements. In the article, the base station deployment is constraint, with the number of base stations and the minimum distance requirement between base stations as the main constraints. A permissible area is used to ensure a relatively reasonable distribution of base stations, as well as to avoid the case of excessive crowding and duplication.

In order to optimize the site selection of base stations, this article defines an objective function to measure network performance and optimization objectives. Neural networks can be used to find the optimal base station location by maximizing coverage and minimizing overall cost or maximizing network capacity.

3.2 Dataset Preparation

Table 1: Partial data

Data ID	Longitude	Latitude	Signal Strength (dBm)	Terrain Height (m)	Building Height (m)	User Demand Met
1	40.7128	-74.006	-80	10	20	Yes
2	40.7213	-73.987	-75	15	25	Yes
3	40.7189	-73.992	-85	8	15	No
4	40.7022	-73.979	-70	5	10	Yes
5	40.7065	-74.009	-90	12	20	No

Dataset preparation is a key process that provides a data foundation for the research of wireless communication base station location and network optimization based on neural networks. Firstly, it collects wireless signal strength data from the real world, and performs data cleaning and processing to remove outliers and noise, ensuring data quality. At the same time, it is possible to obtain geographic information data of cities or regions, such as terrain and landforms, building distribution, etc., and preprocess them to convert them into appropriate geographic coordinate systems. Wireless channel data can be matched with geographic information data to determine signal strength values and geographic features for each location. During the annotation process, corresponding labels can be added to each data sample, such as whether it meets user needs, whether it is within the signal coverage range, etc. The balance and randomness of the dataset can be ensured during the construction process. Finally, data preprocessing is performed, including feature normalization and data balancing, to prepare for the training and optimization of neural network models. Table 1 shows the partial dataset created from the collected data.

3.3 Selection of Neural Network Models

Convolutional Neural Networks (CNN) are a deep learning model widely used in computer vision and image processing tasks. It performs well in processing data with grid structures, such as images, audio, and text sequences, and has made significant breakthroughs in many fields. CNN can play an important role in the selection of wireless communication base stations. Although CNN was originally designed for image processing tasks, its feature extraction and pattern recognition capabilities make it suitable for processing geographic information and signal data related to base station location. Site selection for base stations usually involves considering geographical factors [15], such as terrain, road network, building distribution, etc. By using geographic information data as input, CNN can learn the ability to extract geographic features. Convolutional layers can capture spatial local features in geographic data, such as mountains, rivers, road intersections, etc., providing important references for base station location selection. The location selection of base stations also needs to consider the distribution pattern of signal strength. By using historical signal strength data as input, CNN can learn signal strength characteristics from different regions and predict signal strength for new locations, which is crucial for determining the optimal base station location and coverage range.

3.4 Base Station Site Selection and Network Optimization Strategies

One of the goals of base station location selection is to cover the target area with a network to meet the needs of users. Through reasonable selection and parameter setting of base stations, the target area can be covered to the maximum extent, and the communication signal strength on the ground can meet the expected rate requirement. For example, techniques include the signal propagation model itself being accurately modelled, potentially using data for mapping of terrain and buildings to predict the radio propagation environment, and taking into account the effects from factors like blockage and interference [16].

In addition to coverage, network capacity is also an important optimization goal. When selecting base station location, the distribution of users, communication needs and traffic prediction must be considered, so that base station can reasonably allocate resources and spectrum resources. By optimizing the number of base stations and the configuration of antennas, network capacity and spectrum efficiency can be improved to meet the demand of users for high-speed data transmission.

The interference caused by wireless networks is one of the key factors affecting network performance, and the location of base stations also needs to be accompanied by the strategy to reduce interference in order to improve network capacity and coverage. Through the optimization of base station location and the adjustment of antenna azimuth, it is possible to suppress intra and inter frequency interference effectively. The interference coordination technology (such as power control, angle adjustment, resource allocation algorithm) is used to effectively manage the interference. The quality of wireless networks is introduced to improve the performance of networks [17].

4. Results and Discussion

4.1 Experimental Design

Neural network-based wireless communication base station location and network optimization research is a new method to use deep learning and optimization algorithm, improve the coverage, capacity and interference management of wireless network. The method was calibrated with a large number of geographic information, signal strength, and user distribution data. The equipment learned the fine-grained and massive network intricacies, so that intelligent base station location selection and network optimization decisions could be made. In the experiment, relevant data is first collected and preprocessed, then the CNN structure and parameters are designed, and model training and optimization are implemented using computer equipment and deep learning frameworks. In the experiment, an experimental group and a control group were set up to compare the performance differences between CNN-based methods and Generative Adversarial Networks. The performance and effectiveness of the method can be quantitatively evaluated by evaluating indicators such as coverage, network stability, and network latency. Meanwhile, in order to avoid errors, this article adopts methods such as data preprocessing, cross validation, and experimental repetition to ensure the reliability of the experimental results. This neural network-based method has high intelligence and adaptability, and can dynamically adjust and optimize according to actual situations, thereby improving the performance and user experience of wireless networks. The experimental verification of this method can provide scientific basis for the design and optimization of wireless communication networks, provide effective solutions for improving network coverage and capacity, reducing interference, and promote the development and progress of wireless communication technology.

4.2 Experimental Results

Coverage can tell people how much area the base station signal covers. A higher coverage rate indicates that the base station signal can cover a wider geographical area, providing a wider range of communication services. A low coverage indicates that there may be blind spots with weak or no signals in certain areas. Figure 1 shows the comparison results:

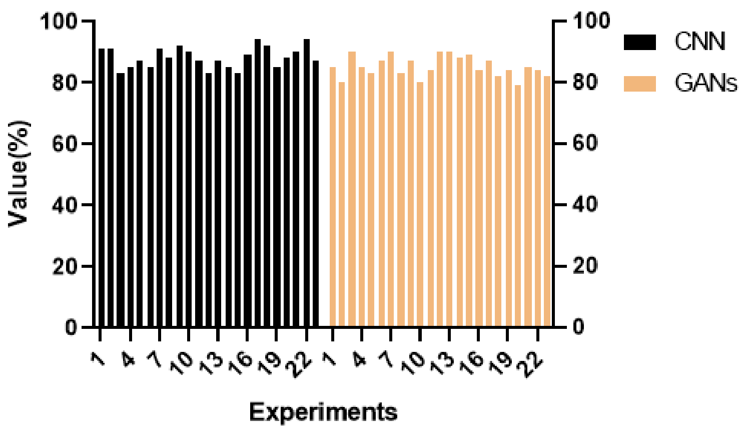

Figure 1: Coverage

In terms of coverage testing, CNN-based coverage can reach 95%, which means that the network can basically be fully covered, and its minimum coverage can also reach 83%, which belongs to a high level of network coverage. The optimization method based on GANs in the control group has a coverage rate of 79% -90%, which is relatively low. CNN can automatically learn the complex patterns and patterns of the network by learning from a large amount of data. In base station location selection and network optimization, a CNN model is used to train a large amount of data, learn the characteristics of geographical regions, user distribution patterns, etc., in order to more accurately determine the location of base stations and improve coverage.

Network stability can reflect the reliability of user connections. A stable network can provide continuous and reliable connections, avoiding situations of disconnection or unstable connections. High network stability means that users can maintain stable connections during communication, reducing the possibility of communication interruptions and packet loss. Figure 2 shows the stability test:

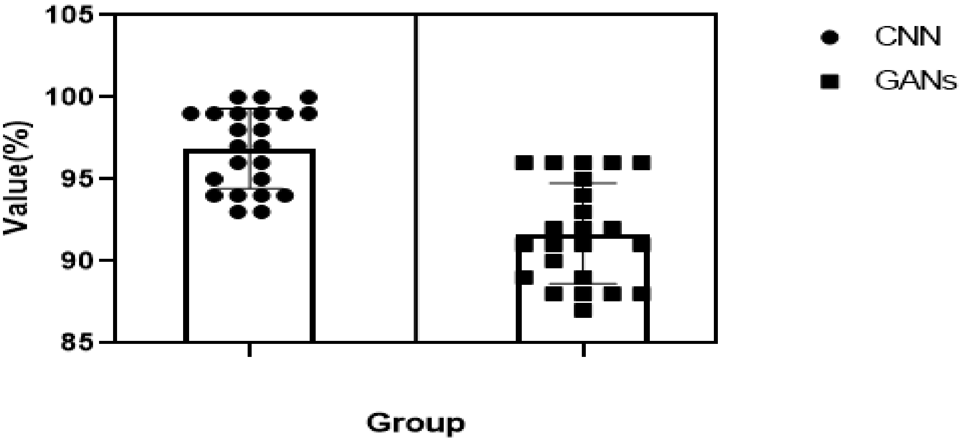

Figure 2: Network Stability

The experimental results show that the network stability of the experimental group in this article is maintained at 93% -100%, while the stability of the control group is maintained at 87% -96%. The maximum value of the experimental group is 4% higher than the maximum value of the control group, and the minimum value is 6% higher. The reason why CNN can achieve such high stability is because it can better adapt to changes in input data by learning the distribution characteristics of a large amount of data during the training process. In base station location selection and network optimization, CNN can predict the location of base stations or optimize network layout by learning geographic information, signal strength data, etc. This data-driven learning approach helps improve network stability and enables the network to better adapt to changes in different environments and scenarios.

Figure 3 shows network latency. Due to CNN's better performance in the above two indicators, only CNN was tested in this experiment.

In Figure 3, a 24-hour network latency test was conducted, and it was observed that the highest latency was 30ms and the lowest was 7ms. The delay is highest at 8 and 12 o'clock, which may be related to network peak periods. By effectively extracting and processing features from signal strength, network topology, transmission paths, and other data, CNN can better capture the factors that cause delay and provide lower latency.

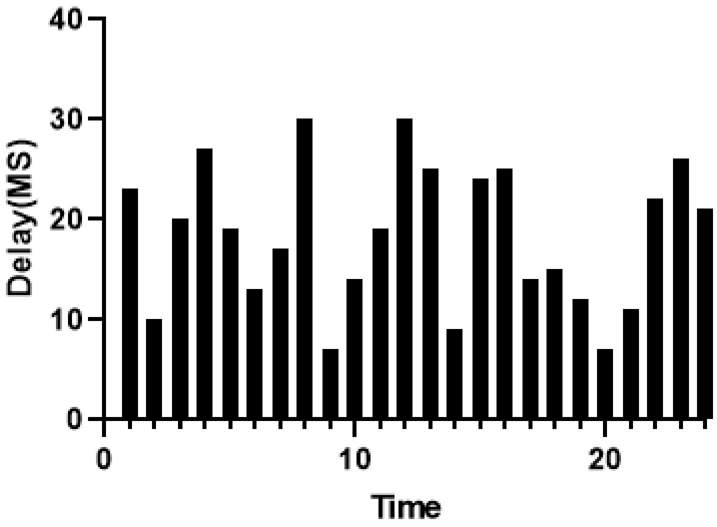

Figure 3: Network latency

4.3 Limitations

The samples and datasets used in testing may not fully represent the diversity of the entire target domain. The differences in user groups and application requirements may lead to different performance of test results in different situations. A wider and more diverse sample selection may better reflect actual usage situations.

The selection of indicators and measurement methods in testing may also have limitations. Although different indicators and measurement methods may be better for evaluating the system in terms of specific aspects, they might not be able to provide a complete and precise picture of the key factors involved.

5. Conclusions

The experimental results showed that the CNN method is effective for the location selection and network optimization of wireless communication base stations, especially for the processing of delay features. As a result, the network latency was effectively reduced. In other words, the processing of delay characteristics by the CNN method is superior, and the network was optimized better. This, to some extent, reflects the strong adaptability and flexibility of this method. It also has certain advantages over adaptive optimization. When processing delay characteristics, it can provide more optimal strategies for different environments and different scenarios. However, some shortcomings and suggestions can be seen in the application of the CNN method for the location selection and network optimization of wireless communication base stations. The sample size should be as large as possible, and the coverage should be as wide as possible, and the diversity should be better. The steps of selecting and adjusting parameters should be simplified and optimized. The quality and reliability of the data should be improved, and the data collection should be uniform and standardized. The experimental design should be more diverse and flexible.

References

[1] Bian Qiang, Xu Donghui, Liu Jiangliang, He Jingyuan, Yang Haiyu.Research on the site selection algorithm of wireless broadband base stations based on hilly areas [J].Journal of Weapons and Equipment Engineering, 2023,

44(2):146-152
[2] Yang Fengyong, Zong Jianfeng, Ma Yang. Research on the optimization algorithm of mobile communication network site planning based on the mean drift algorithm optimized by DBSCA clustering algorithm [J].Progress in Applied Mathematics, 2023, 12(3):847-859
[3] Song Juwei, Zhang Fan.Research and application of site selection of wireless private network base stations for wind power plants [J].Power Information and Communication Technology, 2021, 19(2):75-81
[4] Li Xuegang.The relationship between the site selection and basic design of the communication base station tower [J].Tianjin Science and Technology, 2021, 48(5):31-32
[5] Zhang Lingzhi.Wireless communication network base station coverage analysis and base station site selection design [J].Communication world, 2019, 26(8):198-199
[6] Lai C C, Chen C T, Wang L C. On-demand density-aware UAV base station 3D placement for arbitrarily distributed users with guaranteed data rates[J]. IEEE Wireless Communications Letters, 2019, 8(3): 913-916.
[7] Yang J, Ding M, Mao G, et al. Optimal base station antenna downtilt in downlink cellular networks[J]. IEEE Transactions on Wireless Communications, 2019, 18(3): 1779-1791.
[8] Kishk M, Bader A, Alouini M S. Aerial base station deployment in 6G cellular networks using tethered drones: The mobility and endurance tradeoff[J]. IEEE Vehicular Technology Magazine, 2020, 15(4): 103-111.
[9] Xiao Z, Dong H, Bai L, et al. Unmanned aerial vehicle base station (UAV-BS) deployment with millimeter-wave beamforming [J]. IEEE Internet of Things Journal, 2019, 7(2): 1336-1349.
[10] Wang M, Lin Y, Tian Q, et al. Transfer learning promotes 6G wireless communications: Recent advances and future challenges[J]. IEEE Transactions on Reliability, 2021, 70(2): 790-807.
[11] Al-Ahmed S A, Shakir M Z, Zaidi S A R. Optimal 3D UAV base station placement by considering autonomous coverage hole detection, wireless backhaul and user demand[J]. Journal of Communications and Networks, 2020, 22(6): 467-475.
[12] Zeng S, Zhang H, Di B, et al. Reconfigurable intelligent surface (RIS) assisted wireless coverage extension: RIS orientation and location optimization[J]. IEEE Communications Letters, 2020, 25(1): 269-273.
[13] Wei L, Huang C, Alexandropoulos G C, et al. Channel estimation for RIS-empowered multi-user MISO wireless communications [J]. IEEE Transactions on Communications, 2021, 69(6): 4144-4157.
[14] Wang H, Wan L, Dong M, et al. Assistant vehicle localization based on three collaborative base stations via SBL-based robust DOA estimation[J]. IEEE Internet of Things Journal, 2019, 6(3): 5766-5777.
[15] Wu Q, Liu L, Zhang R. Fundamental trade-offs in communication and trajectory design for UAV-enabled wireless network [J]. IEEE Wireless Communications, 2019, 26(1): 36-44.
[16] Lv Z. The security of Internet of drones. Computer Communications. 2019 Dec 15;148: 208-214.
[17] Jensen Raufelder. Modeling Analysis of Attitude Perception of Engineering Manipulator Supporting Wireless Communication and Internet of Things. Kinetic Mechanical Engineering, 2021, 2(2): 18-26.