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# Enhanced Mobile Coverage Prediction using Stacking and Voting Classifiers

**Mr. Mohammed Abdhahir M[1], Mr. B. Narasimha Rao[2], Mr. D. Narendra[3], Mr. B. Hemanth Kumar[4]**
B.Tech, M.Tech (Assistant Professor), Computer Science and Engineering[1]
**B.E (Students)** , Computer Science and Engineering[2,3,4]
Dhanalakshmi College of Engineering, Chennai, Tamil Nadu
mohamedabdhahir.m@dce.edu.in, narasimharajubaddika225@gmail.com
narendradamera.23@gmail.com, hemanthchowdarypuppy@gmail.com

**Abstract**: *In the age of 5G advancements, accurately forecasting coverage zones has become essential for maximizing network efficiency and ensuring dependable connectivity. This research delivers a detailed evaluation of multiple machine learning techniques aimed at predicting 5G coverage using RF signal data. The prediction models are assessed based on the target attribute, Band Width, to determine their accuracy levels. A wide range of conventional algorithms—such as Logistic Regression, K-Nearest Neighbours (KNN), Naive Bayes, Random Forest, Support Vector Machine (SVM), XG Boost, Light GBM, Ada Boost, Bayesian Network Classifier, Multi-Layer Perceptron (MLP), and Long Short-Term Memory (LSTM)—are compared with more sophisticated methods like Stacking, Voting Classifiers, and Convolutional Neural Networks (CNN). The main goal is to pinpoint the most influential feature parameters that affect 5G coverage prediction. By applying various models, the study sets out to establish a benchmark for prediction performance and reliability. The comparative results shed light on the advantages and limitations of each technique, offering practical insights for both researchers and network planners. Findings reveal that ensemble strategies, particularly Stacking and Voting Classifiers combined with CNN, deliver improved accuracy and resilience, making them strong candidates for optimizing 5G network design and implementation.*

**Keywords**: 5G Signal Forecasting, Machine Learning Models, RF Signal Analysis, Stacking Ensemble, Voting Ensemble, Convolutional Neural Network, Feature Importance, Predictive Accuracy, Network Performance, Ensemble Learning

## I. INTRODUCTION

The emergence of 5G technology marks a transformative shift in wireless communication, delivering exceptional speed, reliability, and connectivity. As the global rollout of 5G infrastructure gains momentum, ensuring optimal network coverage is vital for maintaining consistent service across varied terrains and urban settings. Accurate forecasting of 5G coverage efficiency plays a crucial role in informed network planning and optimal use of resources. This research focuses on the significant challenge of predicting 5G coverage using a rich dataset that includes 27 essential parameters collected from multiple locations. Advanced machine learning approaches—namely Stacking Classifier, Voting Classifier, and Convolutional Neural Networks (CNN)—are utilized to identify the key variables affecting coverage performance. Critical features like Frequency, Signal Strength, Modulation, and Bandwidth are analysed for their influence on prediction accuracy. Ensemble techniques such as Stacking and Voting are employed to integrate the strengths of several models, leading to improved accuracy and reliability. The use of CNNs further enables the exploration of spatial patterns within the data, offering deeper understanding of coverage variation in different environmental contexts. With a dataset containing 164,160 entries, this study thoroughly investigates the impact of each feature and systematically evaluates the performance of the applied models. The results reveal not only the most influential parameters in 5G coverage prediction but also aid in enhancing the accuracy of predictive modelling, which is crucial for strategic network deployment. This research ultimately supports more efficient planning and management of 5G networks, pushing the boundaries of next-generation wireless communication.

## II. OBJECTIVE

The central aim of this study is to perform a detailed comparison of a range of machine learning algorithms—spanning both conventional and advanced methods—for accurately predicting 5G network coverage. Utilizing RF signal data with Band Width set as the target variable, this research evaluates the effectiveness of models such as Logistic Regression, K-Nearest Neighbours (KNN), Naive Bayes, Random Forest, Support Vector Machine (SVM), XG Boost, Light GBM, Ada Boost, Bayesian Network Classifier, Multi-Layer Perceptron (MLP), Long Short-Term Memory (LSTM), along with ensemble approaches like Stacking and Voting Classifiers, and Convolutional Neural Networks (CNN). The overarching goal is to pinpoint the model that offers the best balance between predictive accuracy and computational efficiency, making it well-suited for real-world 5G network planning and optimization.

## III. LITERATURE SURVEY

Sudhamani et al. (2023) conducted an extensive review of current techniques aimed at improving 5G network coverage. Their work highlights the growing complexity of coverage challenges due to increased base station density, which often leads to interference, particularly at cell edges. The study explores various strategies to boost performance, capacity, spectral efficiency, and latency. It also identifies key areas requiring further research to ensure more effective deployment of future 5G systems.

Ahamed and Faruque (2021) addressed the practical concerns of deploying 5G networks, focusing particularly on the shift from mid-band to high-band frequencies. They emphasize that while high-frequency bands provide enhanced capacity, they also suffer from greater propagation loss. To mitigate this, the authors propose a new cell structure with six sectors and advanced antenna systems. Their analysis underscores the operational difficulties mobile network operators face in sourcing adequate small cell locations, which is critical for achieving wide-scale 5G coverage. Future research suggestions are made to help tackle these deployment issues.

Santana et al. (2022) introduced an innovative method for indoor 5G network planning using a machine learning model to estimate path loss, integrated with a Genetic Algorithm. By training their model on two buildings and validating it on three others, they achieved a Mean Absolute Error below 3 DB. Their approach optimizes network design using fewer access points while maintaining performance, and it supports additional design goals like strong signal quality and low RF exposure. This demonstrates significant improvements over traditional heuristic methods.

Fauzi et al. (2p022) examined how supervised machine learning can enhance mobile coverage prediction in an increasingly digitized world. They analyzed several ML models—including Linear Regression, Artificial Neural Networks, and Gaussian Process Regression—for estimating Received Signal Strength (RSRP). Their results showed Gaussian Process Regression as the most accurate, with Random Forest (within Ensemble methods) offering the best balance between speed and accuracy for real-world applications.

Building on their previous work, Fauzi et al. (2023) introduced the Machine Learning-based Online Coverage Estimator (MLOE), a new system built on the Random Forest algorithm. Designed to address current shortcomings in mobile network planning, MLOE utilizes seven distinct input features to forecast network performance. With a Root Mean Square Error (RMSE) of 2.65 dB and an $R^2$ value of 0.93, the model outperforms existing methods. Implemented via MATLAB's Web App Server, it provides a scalable and efficient planning solution for both traditional and emerging mobile networks.

Lastly, Chiroma et al. (2020) discussed the increasing synergy between nature-inspired meta-heuristic algorithms and deep learning applications. Their study categorizes these algorithms based on their utility in enhancing deep learning models, particularly in areas like machine vision, medical diagnostics, and autonomous technologies. While this field is still developing, it holds promising potential for future innovations. The authors call for stronger collaboration between researchers in both communities to unlock new advancements.

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## IV. EXISTING SYSTEM

The current approaches to 5G coverage prediction rely on a wide range of machine learning algorithms, such as Logistic Regression, K-Nearest Neighbors (KNN), Naive Bayes, Random Forest, Support Vector Machine (SVM), XG Boost, Light GBM, Ada Boost, Bayesian Network Classifier, Multi-Layer Perceptron (MLP), and Long Short-Term Memory (LSTM). These models are applied to analyze various feature parameters that influence coverage performance. Each algorithm brings its own strengths in terms of predictive accuracy and computational efficiency, forming a solid foundation for identifying key influencing factors and estimating coverage regions within the dynamic 5G network environment.

**Disadvantages**

Model Complexity and Limited Interpretability: While models like Random Forest and Convolutional Neural Networks (CNN) can deliver high prediction accuracy, their intricate structures often make them difficult to interpret. This lack of transparency can limit their usefulness in guiding practical network planning decisions.

Dependence on Data Quality: These models require large volumes of high-quality data to function effectively. In many cases, such datasets may be incomplete or may not fully capture real-world conditions, leading to biased or unreliable predictions.

High Computational Demand: Advanced algorithms, particularly CNNs, demand substantial computational power for training and deployment. This increases the need for robust hardware and can result in higher energy consumption.

Scalability Limitations: Deploying these models across expansive 5G infrastructures that include millions of connected devices can be challenging. Ensuring real-time prediction at scale remains a significant hurdle.

Difficulty in Adapting to Change: Given the rapidly evolving nature of 5G environments, models trained on historical data may lack the flexibility to respond to new patterns in user behavior or network conditions, limiting their long-term effectiveness.

## V. PROPOSED SYSTEM

The proposed system adopts sophisticated machine learning strategies, such as Stacking and Voting Classifiers alongside Convolutional Neural Networks (CNN), to improve the accuracy of 5G coverage predictions. By integrating these advanced models, the system capitalizes on the unique strengths of each, creating a more resilient and precise predictive framework. The process includes thorough pre-processing of RF Signal Data, followed by model training and performance validation. Through comparative evaluation, the study aims to determine the most effective individual or ensemble model suitable for real-world 5G network planning, ensuring accurate and efficient coverage estimation.

**Advantages**

Increased Prediction Accuracy: Utilizing ensemble methods like Stacking and Voting Classifiers enhances prediction precision by leveraging the combined strengths of multiple models over individual ones.

Greater Stability and Reliability: The ensemble framework addresses the limitations of standalone models, resulting in a more consistent and dependable prediction system.

Enhanced Pattern Recognition: Techniques such as CNNs and ensemble models are more effective at identifying intricate data patterns, which improves the system's ability to generalize across different conditions.

Scalable and Efficient Performance: The use of advanced machine learning ensures the system can process large datasets and deliver accurate predictions efficiently, making it well-suited for real-world 5G network implementation.

**Module Description**

Modules:

- Data Acquisition & Preparation
- Model Development
- Coverage Prediction Analysis
- 5G Data Segmentation

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- User Sign-Up
- User Login & Data Submission

**Dataset Management**

The dataset utilized in this project will consist of essential parameters that influence 5G coverage, including RSRP, SINR, frequency band, base station distance, terrain classification, and device specifications. Data will be obtained through public repositories, simulated environments, or actual field measurements. Preprocessing will involve steps such as data cleaning, managing missing entries, normalization, and converting categorical attributes into numerical form. The dataset will be divided into training, validation, and test subsets using suitable sampling methods. Maintaining data integrity and consistency throughout this process is crucial to developing robust and precise machine learning models for predicting 5G coverage.

**Model Training**

This project involves training several machine learning models—such as Linear Regression, Support Vector Regression, Random Forest, XG Boost, and Neural Networks—on a preprocessed 5G coverage dataset. The data will be split into training, validation, and test sets to facilitate fair performance evaluation. Model optimization will be carried out using hyper parameter tuning techniques like grid search or random search, along with cross-validation. Throughout training, the models will learn to map input variables (such as RSRP, SINR, and distance) to the target outcome, which represents signal quality or coverage. The primary objective is to build predictive models that are both accurate and capable of generalizing across varied environments.

**Predictive Analysis**

In this project, predictive analysis involves utilizing trained machine learning models to estimate 5G signal coverage based on input features such as distance, signal strength indicators (like RSRP and SINR), terrain type, and device-specific attributes. Once the models are trained and validated, they will be evaluated on previously unseen data to measure their accuracy and ability to generalize. Evaluation will be carried out using performance metrics such as Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and the $R^2$ Score. This process will identify which algorithm delivers the most dependable and precise coverage predictions in real-world 5G deployment scenarios.

**Data Segmentation For 5G Coverage Prediction**

In 5G coverage prediction, segmenting the dataset is crucial for achieving accurate and unbiased model assessment. In this project, the data will be split into three key subsets: training, validation, and testing, generally following an 80:10:10 or 70:15:15 ratio. This approach enables the models to learn from the training data, optimize parameters using the validation set, and measure final performance on the test data. Furthermore, segmentation may also consider geographical or environmental categories—such as urban, suburban, and rural areas—to evaluate algorithm effectiveness under different conditions. Stratified sampling methods will be applied when needed to maintain the distribution of critical features across all subsets, promoting balanced and representative analysis.

**User Registration**

User registration serves as an optional module that can be integrated to control access to the 5G coverage prediction platform, particularly when the system is designed as a web-based tool or decision support application. With a secure sign-up process, users—including telecom analysts, researchers, or network engineers—can register using their credentials. This feature allows tailored access to functionalities such as dataset uploads, running predictive models, viewing results, and storing outputs. Implementing user authentication helps maintain data security and facilitates tracking of individual user activity, supporting both collaborative work and operational oversight.

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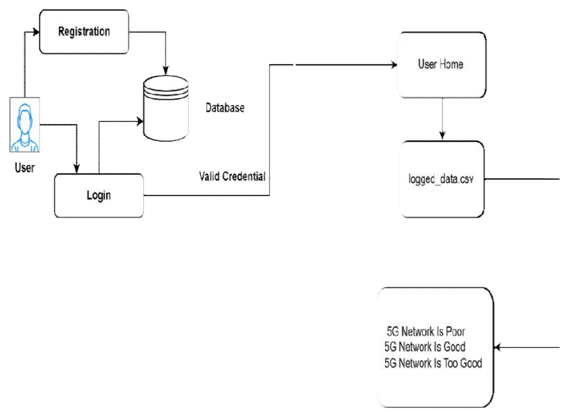
**System Architecture**




## VI. RESULT

The project outcomes demonstrate the comparative effectiveness of multiple machine learning models—including Linear Regression, Random Forest, XG Boost, and Neural Networks—in forecasting 5G signal coverage. Evaluation was based on key performance indicators such as Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and $R^2$ Score to measure prediction accuracy. Among the evaluated models, ensemble techniques like Random Forest and XG Boost delivered superior accuracy and robustness across varying conditions. Furthermore, feature importance analysis highlighted RSRP, SINR, base station distance, and terrain type as the most influential factors affecting 5G coverage. These insights contribute to selecting the most effective models and features for enhancing 5G network design and deployment strategies.

### Comparison

This project evaluates and contrasts the effectiveness of several machine learning models—namely Linear Regression, Support Vector Regression, Random Forest, XG Boost, and Neural Networks—for predicting 5G coverage. Using performance metrics such as MAE, RMSE, and $R^2$ Score, the analysis showed that tree-based models, especially Random Forest and XG Boost, consistently outperformed others in terms of accuracy and resilience. Simpler algorithms like Linear Regression were less effective, particularly in complex or variable environments. These results offer valuable insight into the capabilities and limitations of each method, guiding the choice of the most appropriate model for practical 5G coverage prediction.

## VII. CONCLUSION

In summary, this study underscores the effectiveness of ensemble techniques—such as Stacking and Voting Classifiers—along with Convolutional Neural Networks in accurately predicting 5G coverage. By examining 27 parameters from varied geographic settings, including key factors like Frequency, Signal Strength, Modulation, and Bandwidth, the research identified the most impactful variables influencing network coverage. The results emphasize the value of combining diverse data inputs to boost prediction performance, which is essential for optimizing 5G deployment. Overall, the refined models developed through this work offer meaningful contributions to efficient network planning and provide a foundation for future progress in telecommunications infrastructure.

### Future Enhancement

Future research could aim to improve the accuracy of 5G coverage prediction models by incorporating more detailed spatial and temporal data. Integrating real-time environmental variables—such as weather patterns and urban density—may offer deeper insights into fluctuations in network performance. Additionally, the use of adaptive learning methods that update model parameters in response to changing network conditions could enhance prediction reliability.

Exploring hybrid architectures that combine Convolutional Neural Networks (CNNs) with Recurrent Neural Networks (RNNs) may also prove valuable in capturing temporal trends in coverage behavior.

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