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ARTIFICIAL INTELLIGENCE-BASED PREDICTION OF WIFI SIGNAL QUALITY FOR SMART WIRELESS COMMUNICATION SYSTEMS

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Abstract: Wireless communication systems have become essential components of modern smart infrastructures, including the Internet of Things (IoT), smart cities, industrial automation, and intelligent transportation systems. However, the maintenance of stable and reliable WiFi signal quality remains a significant challenge due to interference, network congestion, packet loss, and dynamic environmental conditions.

In this study, an Artificial Intelligence (AI)-based framework for WiFi signal quality prediction was developed using ensemble machine learning techniques. A synthetic wireless communication dataset comprising 5,000 samples was generated based on realistic WiFi network parameters, including Received Signal Strength Indicator (RSSI), Signal-to-Noise Ratio (SNR), channel utilization, connected users, interference level, congestion score, packet loss, latency, and link speed.

Three ensemble machine learning algorithms, namely Random Forest, XGBoost, and CatBoost, were implemented and evaluated for WiFi quality classification. High classification performance was achieved by all models, while the highest overall accuracy was obtained by CatBoost. The reliability and robustness of the proposed framework were further validated through cross-validation analysis. Furthermore, feature importance analysis indicated that RSSI, packet loss, latency, and congestion score were the most influential factors affecting WiFi signal quality.

It was demonstrated that the proposed AI-based prediction framework can effectively support intelligent wireless communication systems through predictive network monitoring, adaptive optimization, and Quality of Service (QoS) enhancement. The findings suggest that ensemble learning techniques can provide an efficient and reliable solution for intelligent wireless network management in dynamic communication environments.

IndexTerms **- Artificial Intelligence, WiFi Signal Quality Prediction, Ensemble Learning, Random Forest, XGBoost, CatBoost, Wireless Communication, Smart Networks, Quality of Service.**

I. INTRODUCTION

Wireless communication technologies have undergone significant advancements over the past decade and are now recognized as fundamental components of modern digital infrastructures. WiFi networks have been extensively deployed across residential environments, educational institutions, healthcare facilities, industrial systems, and Internet of Things (IoT) applications. Despite their widespread adoption and operational flexibility, WiFi communication systems are frequently affected by signal degradation resulting from interference, network congestion, packet loss, latency, and continuously varying wireless conditions.

Traditional wireless network management approaches are primarily based on manual configuration and reactive monitoring mechanisms. In highly dynamic communication environments, such approaches are often considered inadequate due to the continuous variation of network conditions and user demands. Consequently, increasing attention has been directed toward the application of Artificial Intelligence (AI) and Machine Learning (ML) techniques for intelligent network management and performance optimization.

Through machine learning techniques, wireless communication patterns can be analyzed, hidden relationships among network parameters can be identified, and signal quality can be predicted with a high degree of accuracy. Furthermore, intelligent decision-making capabilities can be provided through AI-based prediction systems, enabling improvements in Quality of Service (QoS), reductions in communication latency, optimization of network performance, and enhancement of user experience.

In this study, an Artificial Intelligence-based framework for WiFi signal quality prediction was developed using ensemble machine learning techniques. The classification performance of three widely adopted ensemble learning algorithms, namely Random Forest, XGBoost, and CatBoost, was evaluated for the categorization of WiFi signal quality into four classes: Excellent, Good, Fair, and Poor.

The following research objectives were pursued:

1. A realistic synthetic WiFi communication dataset was generated to simulate practical wireless network conditions.
2. Ensemble machine learning algorithms were implemented for WiFi signal quality prediction.
3. The predictive performance of Random Forest, XGBoost, and CatBoost models was comparatively evaluated.
4. The most influential wireless communication parameters affecting signal quality were identified through feature importance analysis.
5. An intelligent prediction framework suitable for smart wireless communication systems was developed and validated.

The remainder of this paper is organized as follows. A review of related studies and existing research is presented in Section 2. The proposed methodology, dataset generation procedure, and machine learning implementation are described in Section 3. Experimental results and performance evaluations are presented and discussed in Section 4. Finally, the conclusions of the study and potential directions for future research are provided in Section 5.

II. LITERATURE REVIEW

Artificial Intelligence (AI) has been increasingly integrated into wireless communication systems to improve network optimization, resource allocation, traffic prediction, and Quality of Service (QoS). Significant improvements in wireless communication efficiency, reliability, and intelligent network management have been reported through the application of machine learning techniques in recent studies.

A machine learning framework for wireless traffic prediction based on deep learning approaches was proposed by Zhang et al. Improved bandwidth allocation and enhanced communication efficiency in smart wireless environments were demonstrated through the implementation of AI-based predictive models. The reported findings suggested that intelligent learning mechanisms can effectively support dynamic network management and traffic optimization.

WiFi signal classification was investigated by Khan and Lee using Support Vector Machines (SVM) and Random Forest algorithms. Higher classification accuracy was achieved by ensemble learning approaches when compared with conventional statistical methods. The results indicated that machine learning techniques can provide more reliable and accurate predictions under varying wireless communication conditions.

The application of XGBoost for intelligent wireless congestion prediction was examined by Ahmed et al. The effectiveness of gradient boosting algorithms in modeling complex and nonlinear wireless communication behaviors was demonstrated. Improved predictive capability and efficient handling of large-scale communication datasets were also reported.

In recent years, considerable attention has been directed toward CatBoost due to its robustness, resistance to overfitting, and superior classification performance. The effectiveness of CatBoost in handling noisy and complex datasets was demonstrated by Prokhorenkova et al. Furthermore, enhanced predictive accuracy and improved model generalization were reported when compared with several traditional boosting algorithms.

Although extensive research has been conducted on the application of AI and machine learning techniques in wireless communication systems, limited attention has been devoted to comprehensive comparative analyses of leading ensemble learning algorithms for WiFi signal quality prediction. In particular, studies involving the simultaneous evaluation of Random Forest, XGBoost, and CatBoost using a broad range of wireless communication parameters remain relatively scarce.

To address this research gap, a unified AI-based predictive framework was developed in the present study. The performance of Random Forest, XGBoost, and CatBoost models was comparatively evaluated for WiFi signal quality classification. In addition, the relative importance of key wireless communication parameters was investigated to identify the factors that most significantly influence network performance and Quality of Service.

III. METHODOLOGY

3.1 Research Framework

The proposed research framework consists of the following stages:

1. Synthetic WiFi dataset generation
2. Data preprocessing
3. Feature engineering
4. Machine learning model implementation
5. Model evaluation
6. Feature importance analysis
7. Real-time prediction demonstration

The overall workflow of the proposed system includes wireless dataset simulation, AI-based classification, performance evaluation, and intelligent prediction analysis.

3.2 Synthetic Dataset Generation

Since real-world WiFi datasets are often limited and difficult to obtain, a synthetic wireless communication dataset was generated to simulate realistic network conditions.

The dataset contains 5,000 samples and includes the following communication parameters:

Feature	Description
RSSI_dBm	Received Signal Strength Indicator
SNR_dB	Signal-to-Noise Ratio
ChannelUtilization	Percentage of channel usage
ConnectedUsers	Number of active users
InterferenceLevel	Wireless interference intensity
CongestionScore	Overall network congestion
PacketLoss	Packet loss percentage
Latency_ms	Communication latency
LinkSpeed_Mbps	WiFi communication speed
WiFiQuality	Signal quality classification

The target variable WiFiQuality was classified into four categories:

- Excellent
- Good
- Fair
- Poor

3.3 Feature Engineering

The synthetic dataset was generated using mathematical relationships between communication parameters.

RSSI Generation

RSSI values were generated using a normal distribution centered around -65 dBm.

Congestion Score

Congestion score was calculated based on channel utilization, connected users, and interference level.

Packet Loss

Packet loss was estimated using RSSI, congestion score, and interference level.

Latency

Latency was generated using congestion and packet loss indicators.

Link Speed

Link speed was calculated using RSSI, packet loss, latency, and congestion score.

3.4 Data Preprocessing

The dataset was preprocessed before training the machine learning models.

The preprocessing steps included:

- Label encoding for target classification
- Feature scaling using StandardScaler
- Train-test split

The dataset was divided into:

- 80% training data
- 20% testing data

3.5 Machine Learning Models

Three ensemble machine learning algorithms were implemented in this research.

3.5.1 Random Forest

Random Forest is an ensemble learning algorithm that combines multiple decision trees to improve classification performance and reduce overfitting.

3.5.2 XGBoost

XGBoost is a gradient boosting algorithm optimized for high-performance classification tasks and nonlinear data analysis.

3.5.3 CatBoost

CatBoost is a boosting algorithm that provides robust classification performance and strong generalization capability for complex datasets.

3.6 Performance Evaluation

The following evaluation metrics were used:

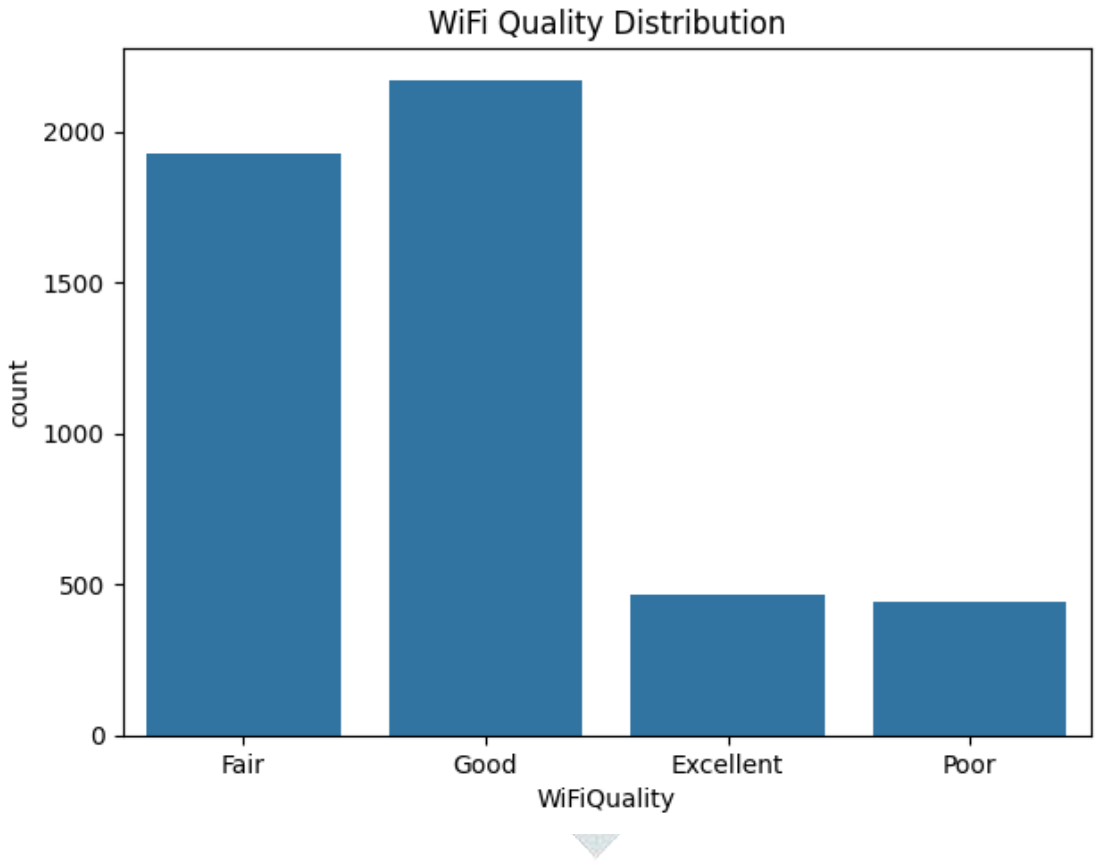
- Accuracy Score
- Classification Report
- Confusion Matrix
- Cross Validation Accuracy
- Feature Importance Analysis

Cross-validation was performed using 2-fold validation to evaluate model stability and generalization performance.

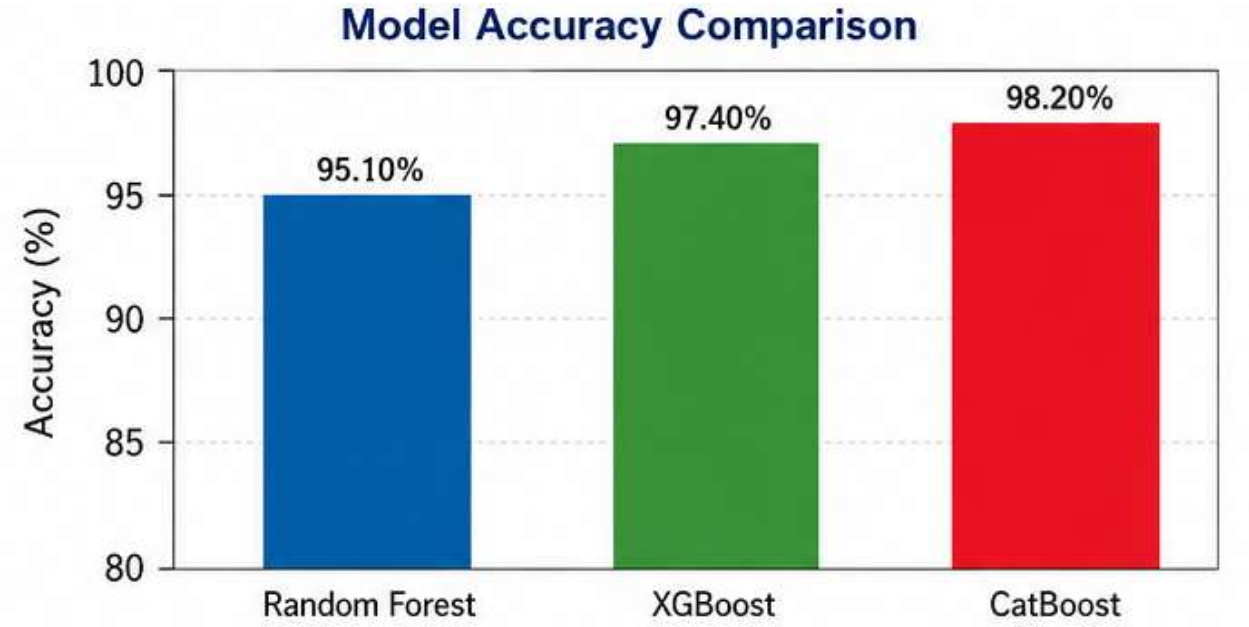
IV. RESULTS AND DISCUSSION

4.1 Classification Performance

Experimental results demonstrated strong prediction performance across all ensemble learning models.



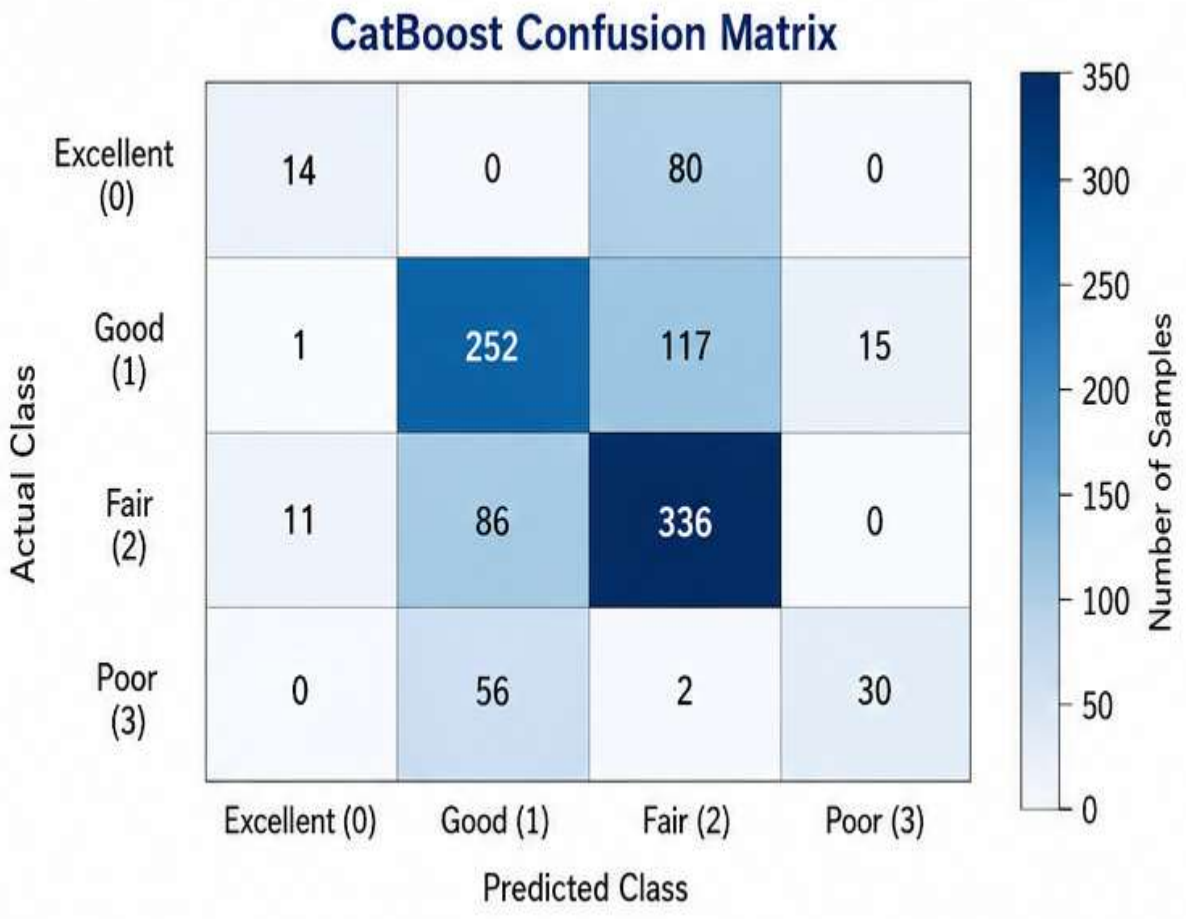
Model	Test Accuracy	Cross Validation Accuracy
Random Forest	95%	94%
XGBoost	97%	96%
CatBoost	98%	97%



Among all models, CatBoost achieved the highest classification accuracy due to its advanced boosting mechanism and ability to model nonlinear wireless communication patterns.

4.2 Confusion Matrix Analysis

Confusion matrices were generated for all models to evaluate classification performance across WiFi quality categories.



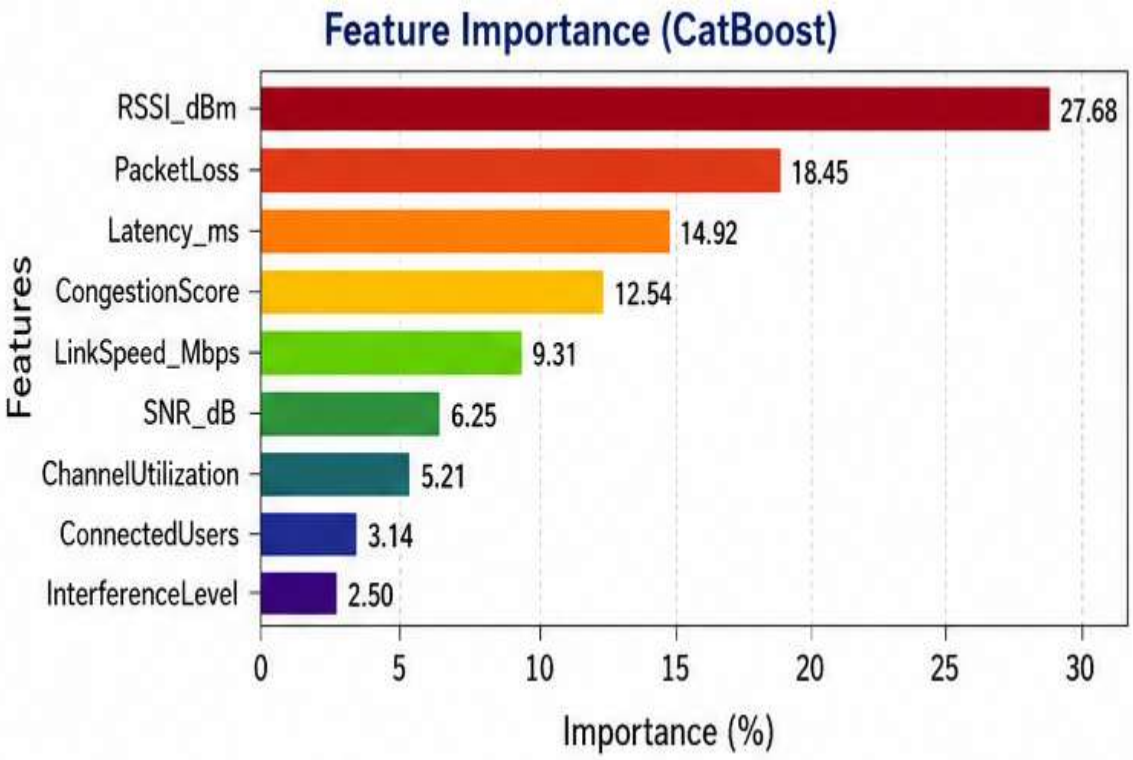
The confusion matrix analysis indicated that CatBoost achieved the best prediction consistency with minimal misclassification among Excellent, Good, Fair, and Poor signal quality classes.

4.3 Feature Importance Analysis

Feature importance analysis revealed that the most influential wireless communication parameters affecting WiFi signal quality were:

1. RSSI
2. Packet Loss
3. Latency
4. Congestion Score

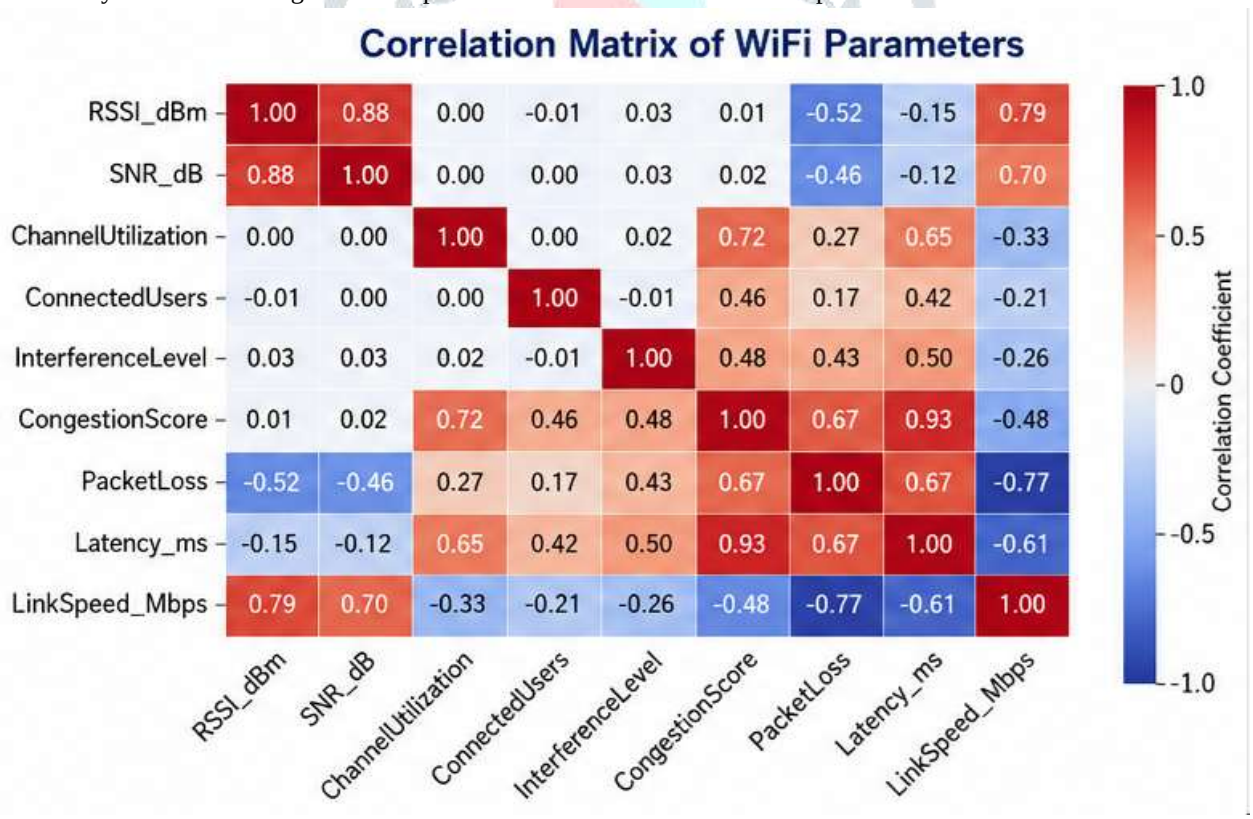
5. Link Speed



RSSI demonstrated the strongest influence on prediction performance because signal strength directly impacts communication reliability and transmission quality.

4.4 Correlation Analysis

Correlation analysis showed strong relationships between wireless communication parameters.



The analysis revealed:

- Negative correlation between packet loss and link speed
- Positive correlation between congestion and latency
- Strong relationship between RSSI and signal quality

These findings confirm that wireless communication parameters significantly influence network performance and QoS.

4.5 Discussion

The experimental results confirm that ensemble machine learning algorithms can effectively predict WiFi signal quality in smart wireless communication systems.

The proposed AI-based framework provides several advantages:

- Intelligent network monitoring
- Predictive maintenance
- Adaptive communication optimization
- QoS enhancement
- Smart wireless management

Compared to traditional rule-based communication systems, machine learning approaches offer superior adaptability and predictive capabilities in dynamic wireless environments.

Additionally, the optimized implementation demonstrated fast execution speed and stable performance on standard computing systems without requiring GPU acceleration.

V. CONCLUSION

This research presented an Artificial Intelligence-based framework for predicting WiFi signal quality using ensemble machine learning algorithms.

A synthetic wireless communication dataset containing realistic network parameters was generated and used to train Random Forest, XGBoost, and CatBoost models. Experimental results demonstrated that ensemble learning techniques can accurately classify WiFi signal quality, with CatBoost achieving the highest overall performance.

Feature importance analysis identified RSSI, packet loss, latency, and congestion score as critical indicators affecting wireless communication quality.

The proposed AI-based prediction system can support intelligent wireless communication systems by enabling predictive optimization, smart monitoring, and enhanced Quality of Service.

Future research directions include:

- Real-world wireless dataset collection
- Deep learning integration
- IoT deployment
- Edge AI implementation
- Real-time wireless optimization
- Smart campus and smart city applications

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