



WiFi Signal Strength Using Geometry: Using Smartphones to Map WiFi Signal Strength and Applying Mathematical Models to Predict Dead Zones and Optimize Router Placement

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ARTICLE INFO	ABSTRACT
Published Online: 16 December 2025	Optimizing WiFi router placement has become crucial for ensuring seamless network coverage with the increasing reliance on wireless internet connectivity in homes and schools. This research investigates the geometric patterns of WiFi signal strength distribution and develops mathematical models to predict dead zones and optimize router placement using smartphones as measurement devices. Through systematic data collection across various indoor environments, we analyzed signal strength patterns using inverse square law modifications, geometric modeling, and statistical regression analysis. Our findings demonstrate that WiFi signal propagation follows predictable mathematical patterns that can be modeled using modified exponential decay functions with obstacle interference coefficients. The developed models achieved 85% accuracy in predicting signal strength at untested locations and successfully identified optimal router placement positions that reduced dead zones by an average of 40%. This research provides practical tools for improving WiFi coverage in residential and educational settings using readily available smartphone technology.
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INTRODUCTION

1.1 Background

The proliferation of wireless devices and internet-dependent applications has made reliable WiFi coverage essential in modern living spaces. Poor router placement often results in dead zones with insufficient signal strength for reliable internet connectivity. Traditional approaches to WiFi optimization rely on expensive professional equipment and complex software solutions that are inaccessible to most users (Cisco Systems, 2020).

1.2 Problem Statement

Current methods for optimizing WiFi placement are either costly professional services or trial-and-error approaches that waste time and may not yield optimal results. There is a need for an accessible, mathematically based approach that can predict signal strength patterns and suggest optimal router placement using commonly available devices.

1.3 Research Objectives

1. To develop mathematical models that accurately represent WiFi signal strength distribution in indoor environments

2. To create a smartphone-based methodology for mapping WiFi signal strength
3. To identify geometric patterns in signal propagation and obstacle interference
4. To develop predictive models for identifying dead zones and optimal router placement
5. To validate the practical effectiveness of the proposed optimization methods

1.4 Significance

This research bridges the gap between theoretical signal propagation models and practical WiFi optimization, making network optimization accessible to students, homeowners, and small businesses using smartphone technology (Mendoza-Silva et al., 2020).

2. LITERATURE REVIEW

2.1 WiFi Signal Propagation Theory

WiFi signals operate in the 2.4 GHz and 5 GHz frequency bands and follow electromagnetic wave propagation principles. The inverse square law governs signal

attenuation, where intensity decreases proportionally to the square of the distance from the source (Rappaport, 2001; Goldsmith, 2005). Molisch (2011) expands on this by addressing indoor-specific factors such as multipath interference and material absorption.

2.2 Indoor Propagation Models

Indoor environments introduce complex variables that affect signal strength. The IEEE 802.11 standard outlines the MAC and PHY specifications for wireless LANs (IEEE 802.11 Working Group, 2020). Cisco Systems (2020) emphasizes the role of walls, furniture, and layout in signal degradation.

2.3 Smartphone-Based Sensing

Smartphones have become viable tools for RSSI-based signal mapping. Laoudias et al. (2021) evaluated RSSI accuracy across devices, noting hardware and orientation variability. MetaGeek (2024) explains RSSI interpretation and its limitations. Mendoza-Silva et al. (2020) provides a comprehensive overview of smartphone-based localization techniques.

2.4 Empirical Datasets

The IEEE DataPort repository (2018) offers open-access datasets of WiFi signal strength collected via smartphones, supporting reproducibility and benchmarking.

3. METHODOLOGY

3.1 Data Collection Setup

Equipment Used:

- Android smartphones with WiFi RSSI reporting capability
- WiFi Signal Strength apps (WiFi Analyzer, NetSpot Mobile)
- Measuring tape for distance measurements
- Grid paper for location mapping

Test Environments:

- Residential home (1,200 sq ft)
- School classroom (600 sq ft)
- Library study area (800 sq ft)

3.2 Measurement Protocol

1. **Grid Mapping:** Each test area was divided into a $2\text{m} \times 2\text{m}$ grid system
2. **Signal Measurement:** RSSI values were recorded at each grid intersection
3. **Multiple Readings:** Five measurements were taken at each point and averaged
4. **Obstacle Documentation:** Physical obstacles were mapped and categorized
5. **Distance Recording:** Direct distance from router to each measurement point was recorded

3.3 Mathematical Modeling Approach

Basic Signal Strength Model:

The signal strength model used is based on the logarithmic path loss formula (Rappaport, 2001): $RSSI(d) = RSSI_0 - 10n \times \log_{10}(d/d_0) - \Sigma WL$

Where:

- $RSSI(d)$ = Signal strength at distance d
- $RSSI_0$ = Signal strength at reference distance d_0 (1 meter)
- n = Path loss exponent
- WL = Wall loss factors
- d = Distance from router

3.4 Data Analysis Methods

1. **Regression Analysis:** Least squares fitting to determine path loss exponents
2. **Geometric Modeling:** Contour mapping of signal strength zones
3. **Statistical Validation:** Cross-validation using holdout test sets
4. **Optimization Algorithms:** Grid search for optimal router placement

4. RESULTS AND ANALYSIS

4.1 Signal Strength Mapping

Measurements revealed distinct geometric patterns in WiFi signal distribution. Signal strength decreased predictably with distance but showed significant variations due to obstacles (Molisch, 2011; Mendoza-Silva et al., 2020).

Table 1: Average Signal Strength by Distance

Distance (m)	Average RSSI (dBm)	Standard Deviation	Sample Size
1-2	-32.4	3.2	12
3-4	-45.8	5.7	16
5-6	-52.1	7.3	18
7-8	-58.7	9.1	14
9-10	-64.2	11.8	10
11-12	-69.8	14.2	8

4.2 Obstacle Impact Analysis

Table 2: Signal Loss by Obstacle Type

Obstacle Type	Average (dB) Loss	Standard Deviation	Frequency
Drywall (1 layer)	3.2	1.1	24
Brick Wall	8.7	2.3	8
Metal Door	12.4	3.1	6
Wooden Furniture	2.1	0.8	18
Concrete Wall	15.6	4.2	4
Kitchen Appliances	6.8	2.9	12

4.3 Mathematical Model Development

Through regression analysis, we developed an enhanced signal propagation model: $RSSI(d,O) = -28.5 - 22.3 \times \log_{10}(d) - \sum(\alpha_i \times O_i) + \epsilon$
Where:

- d = distance in meters
- O = obstacle matrix
- α = obstacle-specific attenuation coefficients
- ϵ = environmental noise factor

Model Performance:

- $R^2 = 0.847$
- $RMSE = 4.2 \text{ dBm}$
- Cross-validation accuracy = 85.3%

4.4 Dead Zone Prediction

Table 3: Dead Zone Characteristics

Environment Type	Dead Zone Threshold	Average Dead Zone Area	Prediction Accuracy
Residential	-70 dBm	85 sq ft	88%
Classroom	-65 dBm	42 sq ft	82%
Library	-68 dBm	126 sq ft	91%

4.5 Router Placement Optimization

Using our mathematical model, we identified optimal router placement positions that minimized dead zones and maximized overall coverage.

Table 4: Optimization Results

Test Environment	Original Dead Zone	Optimized Dead Zone	Improvement
Home Layout	142 sq ft	78 sq ft	45%
Classroom	89 sq ft	34 sq ft	62%
Library Area	203 sq ft	127 sq ft	37%

5. DISCUSSION

5.1 Model Effectiveness

The mathematical model successfully captured the primary factors influencing WiFi signal propagation. The combination of distance-based attenuation and obstacle-specific loss factors provided accurate predictions (Goldsmith, 2005; IEEE 802.11 Working Group, 2020).

5.2 Practical Applications

The smartphone-based measurement approach proved accessible and sufficiently accurate for practical optimization. Users can implement this methodology without specialized equipment (Laoudias et al., 2021; MetaGeek, 2024).

5.3 Geometric Insights

- Signal strength contours revealed interesting geometric patterns:
- Circular propagation zones modified by rectangular obstacle shadows
 - Predictable "shadow zones" behind major obstacles
 - Optimal placement positions often offset from geometric centers

5.4 Limitations

- Several limitations were identified:
- Model accuracy decreased in environments with complex multi-path interference
 - Smartphone RSSI measurements showed device-specific variations
 - Dynamic factors (moving people, changing device loads) were not accounted for

5.5 Future Improvements

- Potential enhancements to the methodology include:
- Machine learning approaches for non-linear obstacle effects
 - Real-time optimization considering network traffic

Integration with building information modeling (BIM) systems

technology and makes better internet connectivity more accessible.

6. PRACTICAL IMPLEMENTATION

6.1 Step-by-Step Optimization Process

Measurement Phase: Map signal strength across the target area using the grid method

Model Application: Apply the mathematical model to predict signal strength at unmeasured locations

Optimization Calculation: Use grid search algorithms to identify optimal router positions

Validation Testing: Verify improvement through post-optimization measurements

6.2 Tools and Resources

Students and practitioners can implement this methodology using:

- Free smartphone apps for WiFi signal measurement
- Spreadsheet software for data analysis and modeling
- Online graphing tools for visualization
- Basic mathematical concepts (logarithms, regression analysis)

7. CONCLUSION

This research successfully demonstrates that smartphone-based WiFi signal mapping, combined with appropriate mathematical modeling, can effectively predict dead zones and optimize router placement. The developed methodology achieved significant improvements in network coverage while remaining accessible to users without specialized equipment or training.

7.1 Key Findings

Mathematical Modeling: WiFi signal propagation follows predictable patterns that can be modeled using modified inverse square law relationships with obstacle-specific attenuation factors.

Prediction Accuracy: Our model achieved 85% accuracy in predicting signal strength at untested locations, making it suitable for practical optimization applications.

Optimization Effectiveness: Optimal router placement based on our model reduced dead zones by an average of 40% across different environment types.

Smartphone Viability: Modern smartphones provide sufficiently accurate RSSI measurements for practical WiFi optimization purposes.

7.2 Practical Impact

The research provides a cost-effective, mathematically grounded approach to WiFi optimization that can be implemented by students, homeowners, and small businesses. This democratizes network optimization

7.3 Educational Value

The methodology serves as an excellent example of applied mathematics, demonstrating how geometric concepts, statistical analysis, and optimization theory can solve real-world problems using commonly available technology.

7.4 Future Research Directions

Future work should focus on:

- Incorporating machine learning for improved obstacle modeling
- Developing real-time optimization algorithms
- Extending the model to outdoor environments
- Creating automated smartphone applications for broader accessibility

This research establishes a foundation for accessible, mathematically based WiFi optimization that bridges the gap between theoretical signal propagation models and practical network improvement solutions.

Declarations

Availability of data and materials

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request. Raw RSSI measurements, obstacle mapping data, and mathematical model parameters used in this study can be provided to researchers for validation and replication purposes.

Competing interests

The authors declare that they have no competing interests.

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