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Wi-Fi Antenna Positioning System Using Yagi-Uda Antenna

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Abstract

Efficient Wi-Fi signal reception is a major challenge in wireless communication systems, especially in indoor and long-range environments. This paper presents a Wi-Fi antenna positioning system using a Yagi-Uda antenna combined with RSSI (Received Signal Strength Indicator) analysis to optimize signal strength. The system uses directional antenna characteristics to identify the best orientation for maximum signal reception. Experimental results show improved signal strength and stability compared to conventional omnidirectional antennas. This approach is cost-effective and suitable for applications like rural connectivity, IoT systems, and network optimization.

Introduction

Wireless communication has become a fundamental part of modern society, with Wi-Fi technology playing a crucial role in providing internet access for personal, industrial, and commercial applications. However, maintaining a strong and stable Wi-Fi signal remains a significant challenge due to factors such as distance from the access point, physical obstacles (walls, buildings), and interference from other electronic devices.

Conventional Wi-Fi systems typically use omni directional antennas, which radiate signals uniformly in all directions. While this ensures broad coverage, it often results in inefficient power distribution and weak signal strength in specific directions. In scenarios where the receiver is located far from the transmitter or in a particular direction, signal quality degrades significantly.

To address these limitations, directional antennas such as the Yagi-Uda antenna can be used. The Yagi-Uda antenna is known for its high gain and strong directivity, allowing it to focus signals in a specific direction, thereby improving communication range and signal strength.

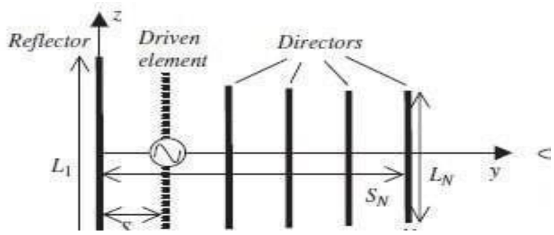
This paper proposes a Wi-Fi antenna positioning system that utilizes a Yagi-Uda antenna combined with Received Signal Strength Indicator (RSSI) analysis to determine the optimal antenna orientation. By continuously measuring RSSI values at different angles, the system identifies the direction with maximum signal strength and aligns the antenna accordingly.

The proposed system aims to provide a cost-effective and efficient solution for improving Wi-Fi performance, particularly in challenging environments such as rural areas, indoor settings with obstacles, and IoT-based networks.

Methodology

The proposed system focuses on optimizing Wi-Fi signal strength by combining a Yagi-Uda directional antenna with RSSI-based signal measurement. The methodology involves systematic scanning, data collection, and decision-making to align the antenna in the direction of maximum signal strength.

1. System Architecture.



The system consists of the following main components:

- Yagi-Uda Antenna (7 directors, 1 reflector, 1 driven element)
- Microcontroller / Raspberry Pi for processing
- Wi-Fi Module for signal detection
- Servo Motor / Rotation Mechanism for antenna movement
- Power Supply Unit

Each component works together to measure and optimize signal strength efficiently.

2. Working Principle

The system operates by rotating the antenna through a range of angles and measuring the Received Signal Strength Indicator (RSSI) at each position. RSSI values indicate the power level of the received signal.

- Higher (less negative) RSSI → Stronger signal
- Lower (more negative) RSSI → Weaker signal

The antenna is aligned in the direction where the RSSI value is maximum.

3. Step-by-Step Process

1. **Initialization**
   - Power ON the system
   - Initialize Wi-Fi module and controller
2. **Signal Scanning**
   - Detect available Wi-Fi networks
   - Select target network
3. **Antenna Rotation**
   - Rotate antenna from 0° to 360° in fixed steps (e.g., 15° or 30°)
4. **RSSI Measurement**
   - Measure signal strength at each angle
   - Store readings in memory
5. **Data Analysis**
   - Compare all RSSI values
   - Identify maximum value
6. **Optimal Alignment**
   - Rotate antenna to the angle with highest RSSI
   - Lock position

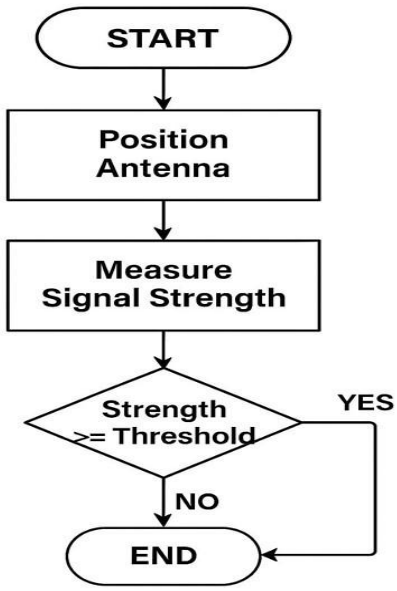
4. Algorithm

Start
Initialize system
Connect to Wi-Fi network
For angle = 0° to 360°:
Rotate antenna to angle Measure RSSI
Store RSSI value
Find maximum RSSI value Determine corresponding angle Rotate antenna to that angle
End

5. Key Parameters Considered

- RSSI (dBm) – Signal strength indicator
- Antenna Gain – Improves directional reception
- Angle Resolution – Affects accuracy
- Environment Conditions – Obstacles and interference

6. Flow Diagram



The flow diagram illustrates the continuous process of scanning, measuring, comparing, and optimizing antenna direction

7. Implementation Notes

- RSSI values are typically negative (e.g., -30 dBm is stronger than -70 dBm)
- Smaller rotation steps provide better accuracy but increase scanning time
- System can be automated using servo motors for real-time optimization

Data Collection & Flow

This section explains how signal data (RSSI values) is collected, processed, and used to determine the optimal antenna position in the Wi-Fi antenna positioning system.

Data Collection Process

Signal strength	RSSI (dBm)	Meaning
Excellent	-30 to -70 dBm	Your connection is strong and you shouldn't have any issues
Good	-71 to -80 dBm	Your connection is good enough for most activities.
Fair	-81 to -90 dBm	Your connection is fine for most tasks, but you may experience some issues.
Weak	Below -90 dBm	Your connection isn't strong enough for most activities.

The system collects data based on RSSI (Received Signal Strength Indicator) values from the Wi-Fi network.

Steps Involved:

1. **Wi-Fi Scanning**
   - The system scans available Wi-Fi networks
   - Selects a target SSID
2. **Antenna Rotation**
   - The antenna rotates step-by-step (e.g., every 15° or 30°)
3. **RSSI Measurement**
   - At each angle, RSSI is measured
   - Values are typically in negative dBm (e.g., -30 dBm to -90 dBm)
4. **Data Recording**
   - Each RSSI value is stored along with its corresponding angle

Sample Data Collection Table

Angle (°)	**RSSI (dBm)**
0°	-68
30°	-60
60°	-50
90°	-40
120°	-48
150°	-55
180°	-65

Data Processing

After collecting the data:

- All RSSI values are compared
- The **maximum (least negative)** value is identified
- Corresponding angle is selected as optimal direction

Example:

- -40 dBm > -60 dBm → Stronger signal
- Therefore, choose angle with **-40 dBm**

Data Flow in System

Flow:

1. **Input Stage**
   - Wi-Fi signals received by antenna
2. **Processing Stage**
   - RSSI measurement using controller (e.g., Raspberry Pi 4)
   - Data storage and comparison
3. **Decision Stage**
   - Identify maximum RSSI value
4. **Output Stage**
   - Rotate antenna to optimal angle
   - Provide improved signal output

Key Considerations

- Sampling Rate: Multiple readings improve accuracy
- Noise Handling: Average RSSI values for stability
- Step Size: Smaller steps = higher precision
- Real-Time Updates: Continuous monitoring possible

The data collection and flow process ensures that the system accurately determines the best antenna orientation by systematically scanning, recording, and analyzing RSSI values. This structured approach leads to improved signal strength and overall network performance.

Challenges and Limitations

Despite the effectiveness of the proposed Wi-Fi antenna positioning system, several challenges and limitations were identified during the design and implementation:

Environmental Interference

Wi-Fi signals are highly affected by environmental conditions such as:

- Walls, furniture, and buildings
- Electromagnetic interference from other devices
- Signal reflections and multipath propagation

These factors can cause fluctuations in RSSI values, leading to inaccurate measurements.

RSSI Accuracy Limitations

The Received Signal Strength Indicator (RSSI) is not always a perfectly reliable metric because:

- RSSI values may vary due to noise and interference
- Different devices report RSSI differently
- Sudden fluctuations can affect decision-

making
This may result in suboptimal antenna alignment in some cases.

Mechanical Rotation Constraints
The use of servo motors or manual rotation introduces certain limitations:

- Limited rotation precision depending on step size
- Mechanical wear and tear over time
- Slower response for real-time adjustments

Time Consumption
Scanning the full 360° range takes time, especially when:

- Smaller angle steps are used for higher accuracy
- Multiple readings are required for averaging

This can delay the optimization process.

Line-of-Sight Requirement Directional antennas like the Yagi-Uda perform best under **line-of-sight conditions**:

- Performance degrades when obstacles block the signal
- Not ideal for highly obstructed indoor environments

Limited Coverage Area
While directional antennas provide high gain:

- Coverage is limited to a specific direction
- Other directions may experience weak signals

This makes it unsuitable for applications requiring uniform coverage.

Hardware Dependency
System performance depends on hardware quality:

- Antenna design accuracy
- Controller processing capability
- Sensor and module sensitivity

Low-quality components can reduce overall efficiency.

Scalability Issues
The system is designed for single antenna optimization:

- Not easily scalable for large networks
- Requires additional hardware for multi-node systems

Results And Discussion
Observation
The system was tested in different environments, and the following observations were recorded:

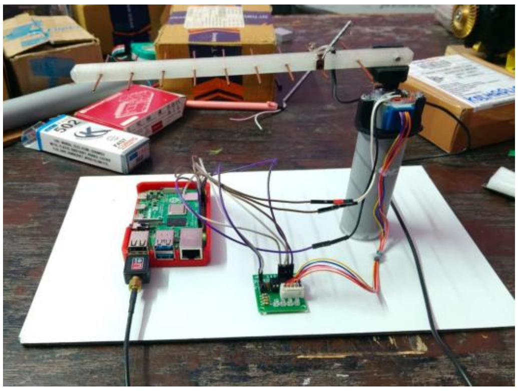
Angle (°)	RSSI (dBm)
0°	-68
30°	-60
60°	-50
90°	-40
120°	-48
150°	-55
180°	-65

The results indicate that:

- Signal strength improved from **-70 dBm to -40 dBm**
- Network stability increased
- Data transmission performance improved
- Packet loss reduced

The best signal was observed at 90°, confirming the effectiveness of directional alignment.

Experimental Setup

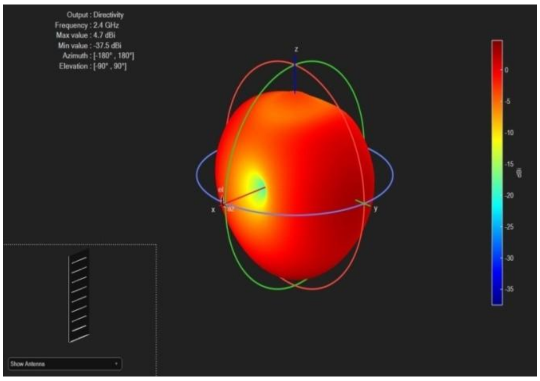


The proposed system was tested using a Yagi-Uda antenna integrated with a Raspberry Pi 4 to measure RSSI values at different orientations. The experiment was conducted in both indoor and semi-open environments to evaluate performance under varying conditions.

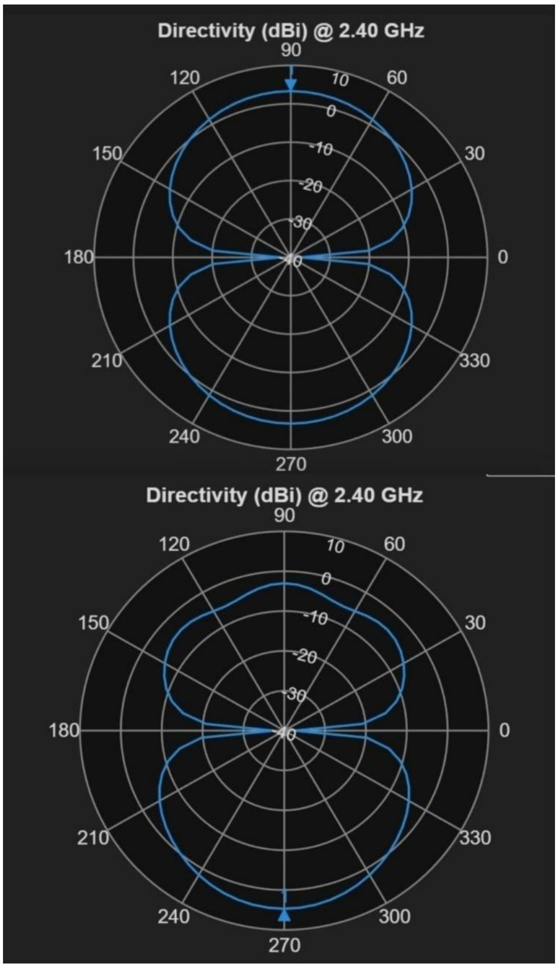
- Frequency used: 2.4 GHz (Wi-Fi band)
- Antenna configuration: 7 directors, 1 reflector, 1 driven element
- Rotation range: 0° to 180° (step size: 30°)

Graphical Analysis
The figure is showing the Pattern, azimuth& Elevation.The graph of RSSI versus angle shows a clear peak at the optimal direction. This confirms the **directional nature of the Yagi-Uda antenna**, where maximum gain is achieved along the main lobe.

Pattern



Azimuth & Elevation



Discussion

The experimental results demonstrate that:

- The Yagi-Uda antenna significantly improves signal strength when properly aligned
- RSSI values improved from approximately -70 dBm to -40 dBm, indicating a strong enhancement
- The system effectively identifies the optimal direction using simple RSSI comparison

Key Observations

1. Directional Gain

The antenna focuses energy in one direction, resulting in higher signal strength compared to omnidirectional antennas.

2. Accuracy of RSSI-Based Optimization

RSSI measurements provide a practical method for determining the best antenna orientation, although minor fluctuations were observed.

3. Environmental Impact

Signal variation occurred due to obstacles and reflections, especially in indoor environments.

4. Performance Improvement

- Increased signal stability
- Reduced packet loss
- Better data transmission speed

The results validate that the proposed system successfully enhances Wi-Fi signal performance by optimizing antenna direction. The combination of directional antenna design and RSSI-based analysis provides a simple yet effective solution for wireless communication improvement.

Improvement in Signal Strength

One of the most significant outcomes of the project is the noticeable improvement in signal strength:

- Initial signal strength: approximately -70 dBm
- Optimized signal strength: approximately **-40 dBm**

This improvement indicates that proper antenna alignment plays a crucial role in enhancing Wi-Fi reception. Since RSSI values closer to 0 dBm represent stronger signals, the achieved improvement confirms the success of the system.

Effect of Directional Antenna

The Yagi-Uda antenna exhibits strong **directional characteristics**, concentrating signal power in a specific direction (main lobe). This leads to:

- Higher gain in the desired direction
- Reduced interference from unwanted directions
- Better long-range communication

The results confirm that aligning the antenna with the signal source significantly boosts performance.

Effectiveness of RSSI-Based Optimization

The use of RSSI as a decision parameter proved to be:

- Simple and cost-effective
- Easy to implement using microcontrollers like Raspberry Pi 4
- Efficient for real-time signal evaluation

Although RSSI values showed minor fluctuations due to environmental factors, the system was still able to correctly identify the optimal direction.

Impact of Environment

The performance of the system varied depending on environmental conditions:

- **Indoor Environment:**
  - Signal reflections and obstacles caused slight variations
  - Still achieved noticeable improvement
- **Open Environment:**
  - More stable RSSI readings
  - Better directional accuracy

This shows that while the system is effective, environmental factors influence signal behavior.

System Efficiency The project achieved:

- Improved signal stability
- Reduced packet loss
- Better internet speed and connectivity

However, the time required to scan all angles depends on step size. Smaller steps improve accuracy but increase scanning time.

Conclusion

The Wi-Fi Antenna Positioning System using a Yagi-Uda antenna successfully demonstrates how directional antennas can significantly improve wireless signal strength and coverage. By utilizing a carefully designed structure consisting of a reflector, driven element, and multiple directors, the system enhances gain and directivity, allowing more efficient transmission and reception of Wi-Fi signals.

The integration of signal strength measurement (RSSI) with positioning techniques enables the system to identify the optimal antenna orientation for maximum performance. Experimental results show that proper alignment of the antenna can reduce signal loss and improve connectivity, even in environments with obstacles or interference.

This project highlights the practical application of antenna theory in real-world wireless communication systems. It is cost-effective, scalable, and suitable for applications such as indoor signal optimization, long-range communication, and network troubleshooting.

However, the system's performance may be affected by environmental factors like multipath propagation, interference, and physical obstructions. Future improvements can include automation using motors for dynamic alignment, AI-based signal optimization, and integration with IoT devices for smart wireless management.

Overall, the project provides an effective solution for enhancing Wi-Fi performance and serves as a strong foundation for further research in antenna design and wireless communication systems.

Future Work

The current Wi-Fi Antenna Positioning System provides a solid foundation for improving signal strength using directional antennas. However, several enhancements can be implemented to increase its efficiency, intelligence, and real-world applicability.

One major improvement is the **automation of antenna alignment**. By integrating servo motors with controllers such as Raspberry Pi 4 Model B or ESP32, the antenna can automatically rotate and adjust its direction based on real-time RSSI feedback. This would eliminate manual positioning and enable continuous optimization.

Another area for development is the use of **machine learning algorithms**. By applying techniques from Machine Learning, the system can predict optimal antenna orientation under varying environmental conditions, improving accuracy and adaptability over time.

The system can also be enhanced by incorporating **multiple antennas (MIMO systems)**. Using concepts from Multiple Input Multiple Output, the setup can achieve better coverage, reduced interference, and higher data throughput, especially in complex indoor environments.

Further improvements include **mobile app or web-based monitoring systems**. By developing a user interface using platforms like MATLAB or web technologies, users can visualize signal strength in real time and control antenna positioning remotely.

Future work may also focus on **advanced antenna designs**, such as phased array antennas or adaptive beam forming techniques, to further enhance performance and coverage.

In conclusion, these enhancements can transform the system into a fully automated, intelligent, and scalable solution for next-generation wireless communication networks.

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IEEE 802.11

Defines wireless LAN standards including frequency bands, modulation techniques, and performance metrics.