Passive Human Detection and RF Mapping using Wi-fi Signals.

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Abstract

This project presents a low-cost passive human detection system using WiFi signals to provide a privacy-friendly detection method without the need for cameras or wearable devices. The main objective of the project is to detect human presence by analyzing changes in RSSI values caused by human presence using two ESP32 devices. The key findings across three different scenarios showed a signal attenuation of 13.2 dBm when a person was standing and 4.6 dBm during movement, which confirms the possibility of using WiFi signals for passive human detection.

Introduction / Background

Traditional human detection systems such as PIR sensors, cameras, and RFID tags provide accurate results, but they are expensive and raise privacy concerns. To develop an effective system, this project uses existing WiFi signals as a privacy-preserving and low-cost solution for passive human detection. WiFi signals are electromagnetic waves that interact with the human body through absorption and reflection while operating at 2.4 GHz. Since WiFi networks are already available in most indoor environments, they can be used as a practical solution for passive human detection. This project is based on previous research that used RSSI variations to detect human presence without requiring any additional wearable devices.

System Model / Methodology

The system consists of two ESP32 microcontrollers placed 1.5 meters apart. The transmitter continuously broadcasts a WiFi access point signal, while the receiver measures RSSI every 200ms and transmits readings via serial communication to a laptop. Data is collected using Python and analyzed in MATLAB. Three experimental scenarios were recorded: empty room, human standing, and human walking. RF mapping was generated by visualizing RSSI distribution as a 5×5 heat map grid to represent spatial signal variation across the environment.

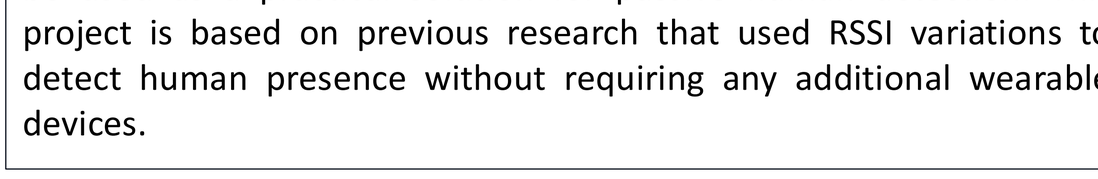


Figure 1. System workflow.

Proposed Solution / Main Idea

The main idea of this project is based on the natural interaction between WiFi electromagnetic waves and the human body. When a person moves between the transmitter and receiver, the body absorbs part of the 2.4 GHz signal, reducing its strength by up to 13.2 dBm in our experiment. In addition, body movement changes the signal path and creates fluctuations due to multipath scattering, where the standard deviation increased to 2.76 during walking compared to 1.99 in an empty room. By monitoring RSSI values and representing them as RF maps, the system can detect human presence using only existing WiFi hardware without relying on cameras or wearable devices.

Results / Simulation / Discussion

- Three experimental scenarios were analyzed: empty room, human standing, and human walking.
- Empty room RSSI averaged -52.3 dBm with minimal fluctuation (Std Dev 1.99), confirming signal stability in the absence of humans.
- Human standing caused a significant drop to -65.5 dBm with an attenuation of 13.2 dBm due to body absorption.
- Human walking averaged -56.9 dBm with higher fluctuation (Std Dev 2.76) caused by dynamic reflection.
- The obtained values fall within the 5–15 dBm range reported by Li et al. (2018) and Dharmadasa et al. (2023), validating the proposed approach.

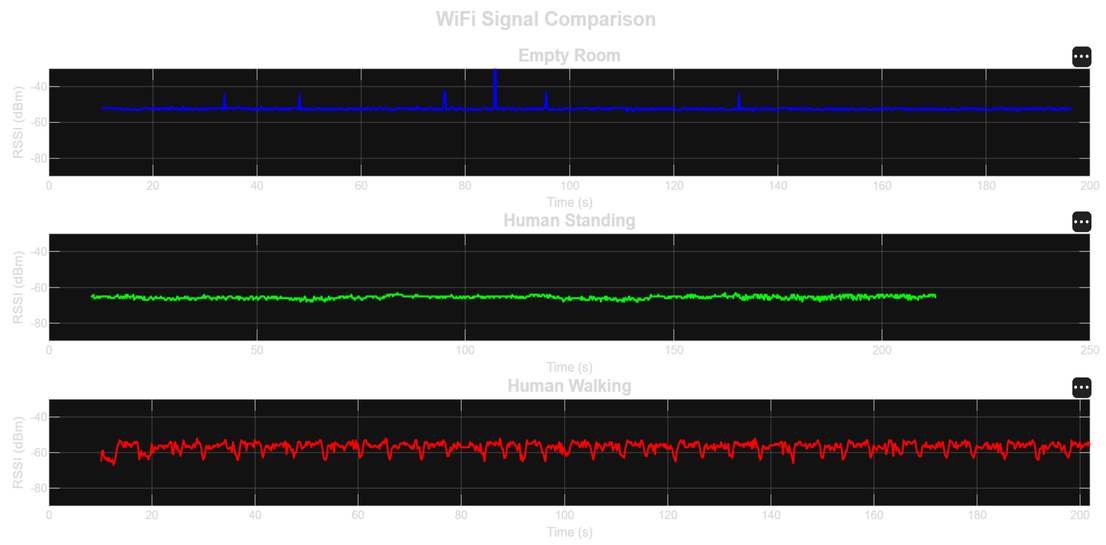


Figure 2. Comparison of RSSI fluctuations over time under empty room, standing, and walking condition.

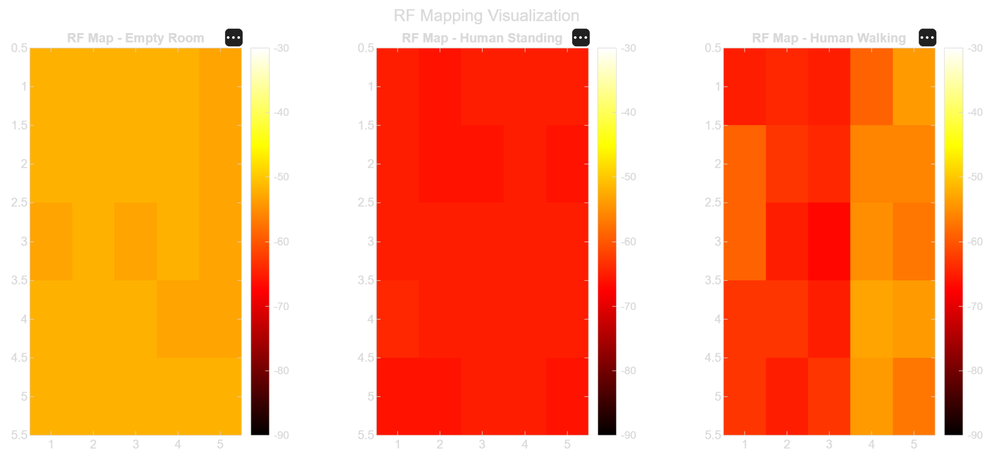


Figure 3. RF mapping results for empty room, standing, and walking scenarios.

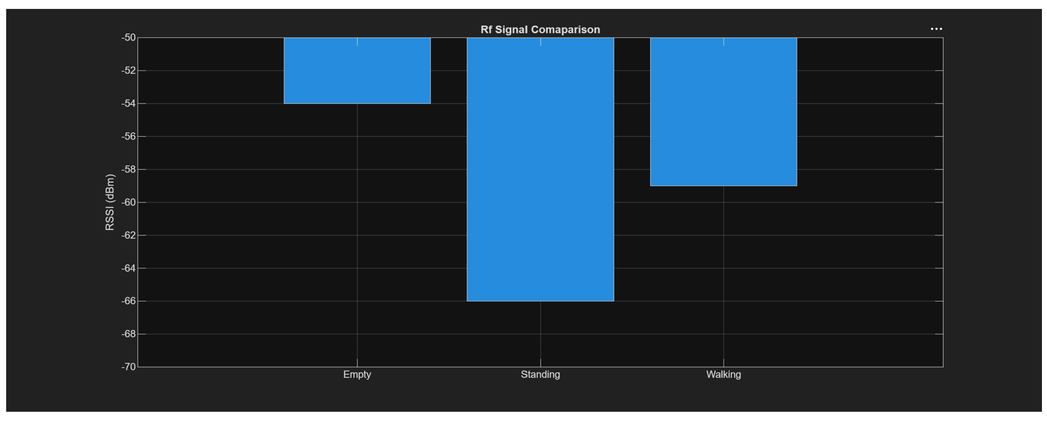


Figure 4. Average RSSI comparison across the three experimental scenarios.

Conclusions

This project has demonstrated and presented a passive human detection system using Wi-Fi signals with RSSI measurement using an ESP32 hardware and matlab analysis. The experimental analysis demonstrated that human presence causes measurable RSSI fluctuations, with a clear attenuation of 13.2dBm was observed when a human was standing, and an increased signal fluctuation (Std Dev 2.76) was recorded during walking. The RF mapping provided intuitive visualization of the signal distribution changes, and the results were consistent with the related literature validating our approach where the system has successfully utilized existing wireless infrastructure to monitor indoor environments without intrusive devices. In the future approaches, we are considering the transition from RSSI to CSI and Doppler effect, also implementing artificial intelligence(machine learning), and expanding testing in larger indoor environments for enhanced coverage.

References