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A Smart Anti-Abduction Device for Child Safety in Public Spaces using RSSI-Based Wireless Monitoring

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Abstract

Child safety has become a major societal concern in crowded public environments where young children are vulnerable to separation from caregivers. Children between the ages of three and seven are particularly susceptible due to their curiosity and limited awareness of potential dangers. This research proposes a compact and cost-effective anti-abduction device designed to alert caregivers when a child moves beyond a predefined safe distance.

The proposed system utilizes wireless communication to establish a connection between a child module and a parent module. Several communication technologies including WiFi, Bluetooth, GPS, and LoRa were analysed to determine their suitability for short-range monitoring. Based on factors such as cost, power consumption, and signal stability, the ESP32 microcontroller with WiFi connectivity was selected as the core component of the system.

The device measures the Received Signal Strength Indicator (RSSI) between the two modules to estimate proximity. When the signal strength drops below a predefined threshold, an audible alert is triggered through a buzzer to notify caregivers. The system operates independently of cellular networks, making it reliable, lightweight, and economical.

The proposed solution offers a practical technological approach to enhancing child safety in public environments and reducing the risks associated with missing children.

Index-terms

Child Safety, Anti-Abduction Device, ESP32, RSSI, Wireless Communication, IoT Safety Systems

I. Introduction

Ensuring the safety of children in public environments has become an increasing concern for parents and guardians. Rapid urbanization, crowded public spaces, and increased mobility have created environments where children can easily become separated from their caregivers.

Children aged between three and seven years are particularly vulnerable during this developmental stage[4]. Their natural curiosity and desire to explore can lead them to wander away from guardians, especially in crowded environments such as shopping malls, railway stations, airports, amusement parks, and large public gatherings[5]. Even a brief moment of distraction may result in a child getting lost, which can lead to panic, accidents, or in extreme cases, child abduction.

Recent reports indicate that a significant number of missing child cases occur in public locations where supervision becomes difficult. While traditional methods such as parental supervision and community awareness remain important, technological solutions can provide an additional layer of protection.

This research focuses on developing a **compact wireless anti-abduction device** that alerts parents when their child moves beyond a safe distance. The system utilizes wireless signal strength monitoring to determine proximity and trigger alerts when separation occurs.

II. Literature Review and Technology Analysis

Several wireless technologies were evaluated for their suitability in proximity monitoring systems. Each technology presents advantages and limitations depending on the application requirements.

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2.1 Bluetooth Communication

Bluetooth technology is widely used for short-range wireless communication and low-power devices. However, Bluetooth is susceptible to interference in the 2.4 GHz frequency band and may experience connection instability in crowded environments[3].

2.2 LoRa Communication

LoRa technology is designed for long-range communication with low power consumption. While it is effective for large-distance communication in IoT applications, it provides less accurate RSSI values for short-distance proximity monitoring and requires additional antenna components.

2.3 GPS Tracking

GPS modules provide accurate location data for long-distance tracking applications. However, they consume significant power, require additional communication modules for data transmission, and often perform poorly in indoor environments.

2.4 WiFi Communication

WiFi-based communication offers reliable connectivity and the ability to monitor signal strength through RSSI values. It is cost-effective, widely supported, and suitable for short-range proximity detection.

Based on these factors, WiFi communication using the **ESP32 microcontroller** was selected as the most suitable technology for the proposed system.

III. System Design and Methodology

The proposed system consists of two main modules:

1. **Child Module**
2. **Parent Module**

Both modules communicate through WiFi using the ESP32 development board.

3.1 Hardware Components

ESP32 Development Board

The ESP32 serves as the primary microcontroller and wireless communication unit. It features integrated WiFi and Bluetooth connectivity, a dual-core processor, multiple GPIO pins, and low power consumption, making it ideal for IoT applications[1][2].

Piezo Buzzer

A piezoelectric buzzer is used to generate audible alerts when the signal strength indicates that the child has moved beyond the safe distance.

Lithium Polymer Battery

A lightweight lithium polymer battery provides portable power to the device. Its compact size and high energy density make it suitable for wearable or portable electronics.

Voltage Regulation Components

A DC-DC boost converter (MT-3608) regulates the power supply voltage for the ESP32 module, while a BC547 transistor controls the buzzer operation.

IV. Working Principle

The system operates by monitoring the **Received Signal Strength Indicator (RSSI)** between the parent module and the child module.

RSSI represents the power level of a received wireless signal and is typically measured in decibels (dBm). Values closer to zero indicate stronger signals, while more negative values indicate weaker signals[6].

Typical RSSI ranges include:

- −30 dBm : Excellent signal strength
- −60 dBm : Good signal strength
- −80 dBm : Weak signal strength

As the distance between the child and parent modules increases, the RSSI value decreases. When the RSSI value falls below a predefined threshold (approximately −75 dBm), the system identifies that the child has moved beyond the safe distance.

At this point, the system triggers the buzzer alert to notify the caregiver immediately.

V. System Operation

The device operates through the following sequence:

1. The child module is powered on and initializes a WiFi access point.
2. The parent module connects to the child module via WiFi.

Name	Pros	Cons
ESP-Now communication	Good for local data transfer and mesh net work	Unstable RSSI values for this project
Bluetooth communication	Good for short istance datatransfer	Susceptible to 2.4gz noise and cant work bidirectional same time
LORA (sub gigahertz)	Good for long distance communication IoT platforms	RSSI values not suitable for this project. External antenna not fit for this project
GPS module	Good for long distance tracking	Low accuracy at short distances, high cost, need for internet (GSM module integration)for location transfer , increase in complexity & weight.
Hence , simple WIFI signal RSSI values and webserver was used in this project to maintain cost effectiveness, compactness, robustness, simplicity in design		

3. Once connected, both modules begin monitoring signal strength.
4. As long as the RSSI value remains within the safe range, the system remains in monitoring mode.
5. If the signal strength drops below the threshold, an alert is triggered through the buzzer.
6. The caregiver is immediately notified of the potential separation.

The effective monitoring range is approximately **15 to 20 feet**, although environmental factors such as obstacles and wireless interference may affect signal strength.

VI. Results and Discussion

The prototype device successfully demonstrated the ability to monitor proximity between the child and caregiver using RSSI-based wireless communication. Testing showed that the system reliably triggered alerts when the child moved beyond the predefined safe distance.

The device remained stable in typical indoor environments such as classrooms and corridors. However, signal variations were observed in environments with heavy WiFi interference or physical obstacles.

The lightweight design and battery-powered operation make the system practical for everyday use.

Additionally, the absence of cellular connectivity reduces operational costs and complexity.

Pros and Cons of wireless technologies

VII. Conclusion

This research presents the design and implementation of a smart anti-abduction device aimed at improving child safety in public environments. By utilizing RSSI-based wireless communication through the ESP32 platform, the system provides a simple and effective method for monitoring proximity between children and caregivers.

The proposed device is compact, affordable, and easy to operate, making it suitable for real-world implementation. With further enhancements such as wearable integration, mobile application connectivity, and improved signal processing algorithms, the system could evolve into a more advanced child safety solution.

The integration of such technologies has the potential to significantly reduce the risks associated with missing children and enhance community safety.

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