Faculty: SIT and UoG – Computing Science

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Project Title

GuardianCare – IoT-Based Fall Detection System

BSc (Hons) in Computing Science

Introduction and Problem Statements

Falls are a major risk for seniors, especially those living alone. In Singapore, 1 in 3 aged 65+ have experienced a fall — **40%** of which have led to injury-related deaths.

With over 19% of the population now aged 65 and above (projected 25% by 2030), there's a growing need for **real-time**, **private**, and **accurate fall detection** solutions.

Current systems often rely on cameras or sensors that:

- Raise privacy concerns
- Fail to detect falls in personal spaces (e.g., bedrooms, bathrooms)
- Lack real-time alerts

Our system addresses these issues by providing a **scalable**, **reliable** fall detection system using IoT technology that ensures **privacy** and delivers **real-time** alerts.

Methodology and Proposed Solutions

Our fall detection system uses a **hybrid IoT communication network** combining **ESP-NOW** (for short-range, fast peer-to-peer data transmission) and **LoRa** (for long-range communication). Using M5StickCPlus devices to simulate fall detection, this system delivers **instant alerts** to caregivers via a **web application**. With **AES encryption**, we ensure secure communication, while **scalability** supports up to 50 devices per block. The system is energy-efficient, optimizing battery life, and provides an ideal solution for elderly care environments such as HDB blocks and community care facilities.

System Design:

- **Hybrid Wireless Communication**: The system uses a combination of ESP-NOW for local, low-latency communication and LoRa for long-range data transmission. This combination allows the system to address key challenges such as power consumption, network range, and scalability.
- **M5StickCPlus**: These devices are used for fall detection. They collect fall events via a button press, simulating the detection of falls. The fall event data is then transmitted to a central system via the ESP-NOW and LoRa protocols.

Data Transmission & Storage:

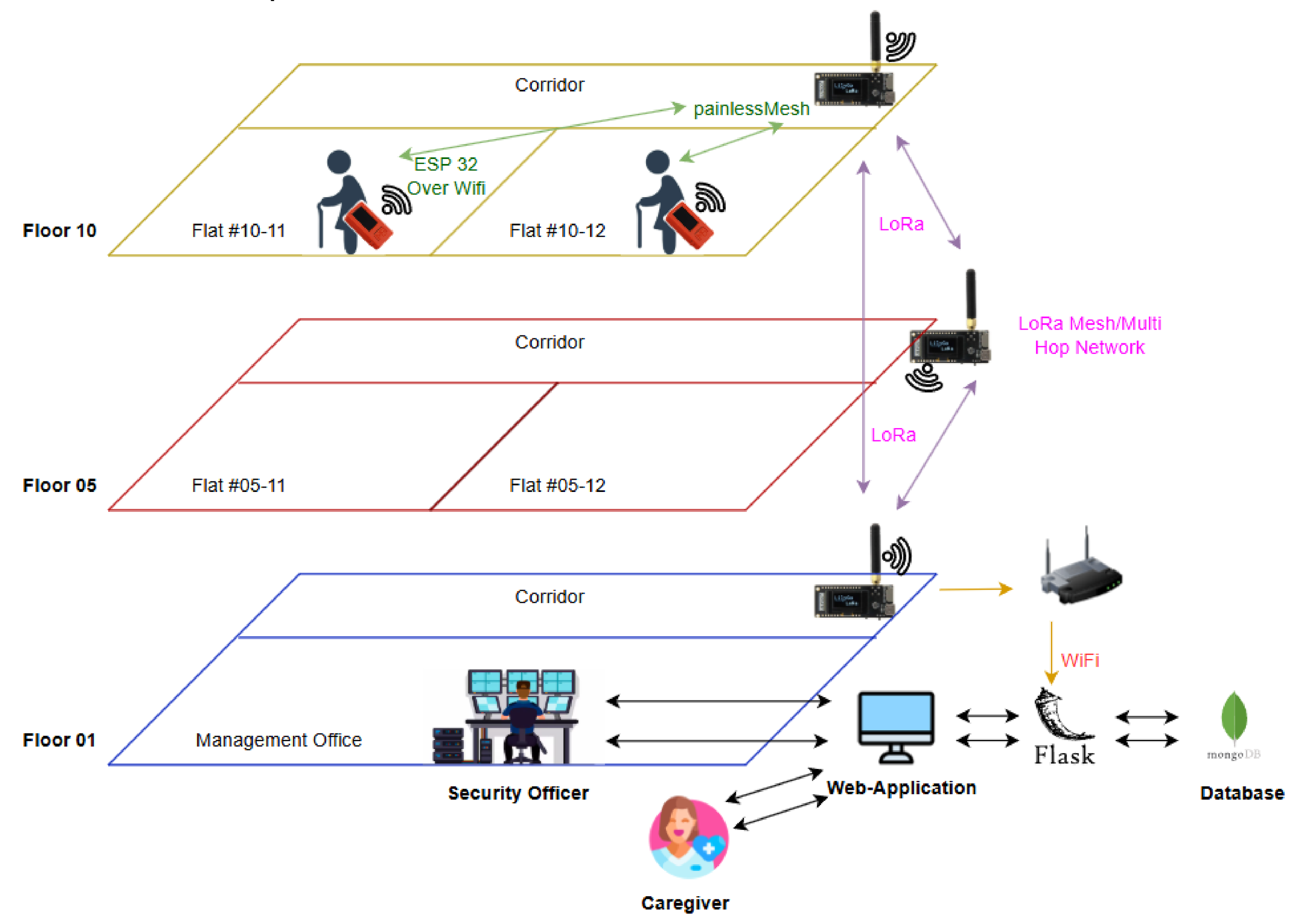
- The M5StickCPlus communicates with the Starting LilyGO via ESP-NOW and then forwards the data to the Final Destination LilyGO using LoRa for long-range transmission.
- Data from the Final Destination LilyGO is sent to the Flask server, where it is processed and stored in a MongoDB database.

Security:

- Data is encrypted using **AES encryption** during transmission via LoRa and encrypted through **Wi-Fi** protocols during transmission via ESP-NOW ensuring secure communication across the network.

User Interface:

- A Web Application is provided to caregivers for real-time monitoring and receiving alerts, displaying fall events with timestamp details.



Research Questions and Project Objectives

Research Questions:

1. How does the combination of ESP-NOW and LoRa protocols address the challenges of power consumption, range, and scalability in fall detection systems for elderly individuals?
2. In what ways does ESP-NOW improve local communication in environments like elderly care homes, compared to protocols such as Zigbee or Wi-Fi?
3. How does LoRa's long-range capability improve the reliability of fall detection systems in remote or large-scale environments, compared to Wi-Fi or LTE-based systems?

Project Objectives:

1. Develop a real-time fall detection system using M5StickCPlus devices, incorporating ESP-NOW for low-latency local communication and LoRa for long-range data transmission.
2. Implement a hybrid communication network combining ESP-NOW and LoRa to minimize power consumption, increase range, and enhance scalability, addressing limitations of Wi-Fi, Bluetooth, and Zigbee.
3. Enable efficient multi-hop communication with LoRa relay nodes, ensuring system scalability and coverage across larger environments, such as HDB flats, elderly care homes, and hospitals.

Experiments and Results Analysis

To thoroughly evaluate the fall detection system, we conducted a series of controlled experiments focusing on various system aspects, including performance, reliability, and scalability. The experiments were designed to measure the system's capability to detect falls, transmit data efficiently, and ensure minimal latency in real-time operation.

Devices Used:

- **5 M5StickC Plus devices**: Used as the wearable sensors for detecting simulated falls.
- **3 LilyGO T3-S3 relay nodes**: One acting as the floor level node, one acting as relay node in a multi-hop LoRa configuration, and one acting as the management office node to forward data to the Flask server for processing.

Communication:

- **Short-Range Communication**: Utilized ESP-NOW and Wi-Fi to enable communication between M5StickC devices and the starting LilyGO node.
- **Long-Range Communication**: Used LoRa for long-range data transmission between the starting LilyGO, middleman relay nodes, and the final destination LilyGO.

Environment:

The system was tested in a controlled setup where simulated falls were triggered via button press events on the M5StickC devices, mimicking real fall incidents. The testing environment was designed to reflect typical usage in environments such as elderly care homes or residential blocks.

Key Metrics

- **Response Time**: Time from fall detection to alert transmission.
- **Data Throughput**: Rate of data transmission between devices.
- **Latency**: Delay in communication between devices.
- **Reliability**: Success rate of message delivery under varying conditions.
- **System Accuracy**: Precision in detecting falls and sending alerts.

Results:

Key Metrics	Short-Range	Long-Range
Response Time	Average of 1 second from button press to server update, well within the target of under 5 seconds	Response time was slightly higher for LoRa due to multi-hop communication, but it was still effective.
Data Throughput	Smooth transmission for a single device. Minor delays under high traffic but not significant.	LoRa experienced minor delays under high load but did not significantly affect performance
Latency	The latency for ESP-NOW communication was negligible, with no issues reported.	LoRa communication experienced higher latency due to the nature of long-range transmissions, with delays of approximately 600-1000ms.
Reliability	Reliable communication with minimal packet loss in ESP-NOW.	Occasional packet loss (3-4 failures out of 20 tests) in LoRa communication, mainly due to LoRa's best effort nature.
System Accuracy	100% accurate in detecting simulated fall (button presses). No false positives observed	100% accuracy in fall detection, even with occasional packet drops in LoRa communication.

Conclusions and Future Work

Conclusion

This IoT-based Fall Detection System effectively addresses the critical need for real-time fall detection among the elderly. By integrating ESP-NOW for local communication and LoRa for long-range transmission, the system ensures reliable, low-latency communication and real-time alerts, even in areas with weak network coverage. The system's performance in terms of response time, latency, and scalability demonstrates its strong potential for deployment in elderly care environments, making it a valuable tool for improving safety and response times.

Future Works

- **Implement Real Fall Detection**: Use M5StickCPlus sensors for actual fall detection.
- **Improve LoRa Communication**: Reduce latency and packet loss in LoRa transmission.

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