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Smart Box System for Intelligent Occupancy Detection and Fire Safety Automation in Rental Properties

Michael Joseph R. Pelaez, Dr. Aristotle F. Musni

San Beda College Alabang

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ABSTRACT

This study describes the design and implementation of a Smart Box System that autonomously detects guest occupancy in rental units and automatically triggers fire-safety measures. It leverages IoT tools to ease the challenge of monitoring occupied units remotely. Throughout the system, motion sensors detect real-time activities, and fire detectors transmit early warning signals the moment smoke or heat is sensed. ESP32 boards manage the sensors together, while MQTT carries the measurements to a cloud server. Consequently, a single web dashboard provides owners with clear updates on occupancy and any unusual temperature readings, thereby lessening the need for property visits. Similarly, the presence of guests, risks, and hazards can be monitored briefly.

This solution was installed in short-term rentals across Biel, Crosswinds, Tagaytay, Philippines. Guest presence was detected with an accuracy of more than 95%, whereas fire alerts reached smartphones in less than 20 seconds. Owners reported fewer onsite visits of 40%, proving the system streamlines daily duties without compromising safety for guests.

The research adds real value to property owners by demonstrating how IoT devices paired with cloud services allow owners to monitor rental activities in real-time, ensure guest safety, and run daily operations more efficiently.

INTRODUCTION

While platforms such as Airbnb previously refined means homeowners can generate residual income, particularly via short-term leases, overseeing lodgings located remotely invariably poses difficulties. Property owners commonly relied on managers to assume responsibilities, including documenting occupant figures and guaranteeing satisfactory conditions. Some homeowners found logistics irksome, but renting spare areas helped subsidize living expenses—though continual engagement remained imperative for sustaining hospitality standards in lodgings (Folger, 2024).

One major constraint for owners was accurate information on occupancy. Payments relied on the number of nights booked, whereas incorrect data on the number of guests could signify significant losses. Since the locations were often considered distant, it had become inconvenient for owners to regularly confirm how many guests were staying or oversee the property's condition (Alyse, 2024).

Similarly, safety was a crucial factor. Fire and other hazards can be inconspicuous, risking the place and its guests. With technologies like remote monitoring, owners can receive real-time updates from devices like motion sensors for guest detection and fire alarms. This could give them the power to manage their rentals more securely from a distance (Nettelbeck, 2022).

This study focused on developing a system for remotely tracking occupancy and detecting fire hazards for short-term rentals in Biel, Crosswinds, Tagaytay. By using automated tools, owners can receive accurate reports, protect their properties, and ensure efficient management.

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METHODOLOGY

The overall layout fused the IoT sensor ring into a single framework that bundled every data source. Core parts are sensors, a microcontroller, a Wi-Fi module, power circuits, and gateways that grab and relay the raw readings. A central manager processes those inputs live, leaning on the cloud for long-term storage and apps. Dashboards and log displays turn numbers into pictures so staff can watch the surroundings in brief. Sensors are positioned on each corner to track rental space temperature, pressure, fire, smoke, leaks, and movement with devices like BME680, LDR, MLX90614, RCWL-0516, and leak alerts. An ESP32 ties them together, sending results to the Wi-Fi gate while a steady power feed keeps the whole ring alive.

Gateways acted like middlemen, gathering numbers from small controllers and sending them to the main system through a locked cloud link. Clear, legible screens, then colored those figures in live dashboards popped up, complete with alerts and a look-back option. A mesh setup was on the table to boost reliability, letting data travel several roads, cutting failure chances, and polishing overall performance.

ESP32 microcontroller collected environmental data from various sensors and sent it to an IoT Cloud platform for monitoring and visualization purposes. The ESP32 functioned as a central processing unit, communicating with these sensors, and collecting, processing, and sending data to the cloud using Wi-Fi. The entire system was powered by a 5V DC power supply to the ESP32 and the sensors, with a 10uF capacitor added to provide stability against fluctuations from the power supply that could have affected the performance of the sensors.

The sensors were set up to measure different parameters of the environment. A BME680 sensor measured temperature, humidity, gas levels, and pressure; an MLX90614 infrared sensor measured the temperature of objects remotely; a Light-Dependent Resistor (LDR) measured light intensity as its resistance varied with ambient light; an RCWL-0516 microwave radar sensor detected motion via a digital signal output; and a water leak sensor (YL-99) detected water leakages by sensing conductivity when water bridged its traces. All these sensors were connected to the specific GPIO ports of the ESP32, where power was fed by 5V.

The ESP32 processed all the information and data collected from all those sensors attached and communicated the same to the IoT Cloud via Wi-Fi. As a result, this cloud platform could provide an output to display a real-time dashboard of factors such as room temperature, humidity, or even gas levels, along with motion detection. Evidently, this was a great platform for home, environmental monitoring, or any other IoT project that necessitated remote monitoring and analysis. Moreover, through the incorporation of sensors, the microcontroller, and cloud technology, the system ensured a seamless solution for monitoring diverse environmental parameters.

System Accuracy and Performance

The system achieved a guest detection accuracy rate of **98.4%**, measured through the correlation of motion detection logs with actual guest entries. Fire and hazard warnings appeared in less than 20 seconds, proving that the system reacts quickly during adversities. During thirty straight days of monitoring, the setup stayed online 99.1 percent of the time.

User Evaluation

Alpha and beta testing results indicated high satisfaction levels:

- **Functionality**: 4.75 out of 5 (Mean)
- **Usability**: 4.80
- **Reliability**: 4.67
- **Efficiency**: 4.68

Testers liked how the dashboard felt natural and how it showed sensor activity live. Tech staff pointed out that the software slid into their current Wi-Fi setup, and everyday users stressed it was simply easy to use.

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Operational Impact

Feedback from property owners indicated a **40% reduction in site visits**, attributed to the confidence gained from real-time alerts and visual data reports. All users reported timely receipt of alerts for motion or environmental threshold breaches.

DISCUSSION

The Smart Box System addressed common constraints in rental management by allowing automation to boost efficiency, safety, and personal convenience. Motion sensors tracked occupancy in real time, so owners skipped manual logs and site trips while billing guests accurately. The built-in fire alarm detected smoke and heat, sent an alert in less than twenty seconds, and left managers adequate time for response. By merging fire alerts with occupancy data into one dashboard, it created a single tool that ensured both safety and oversight. Owners highly favored the system for stronger security, smoother operations, and renewed guest trust. Evidently, automation has eased the management of rental properties.

CONCLUSION

The new occupancy and fire alert system makes short-term rental management smoother by remotely monitoring occupancy and safety. Using simple motion sensors, it sends instant guest counts that reduce housekeeping guesswork and help bill accurate costs.

It's built-in fire monitor notifies owners and responders in under 20 seconds, leaving enough time to respond to an emergency. As it is relatively fast, the system meets the standards for local safety codes. By merging occupancy tracking and fire alerts into a single dashboard, the setup reduces the need for site trips and allows managers to efficiently monitor several homes.

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