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Enhancing Residential Security Systems: Integrating GSM Technology and Phone Call Alerts

Eneh Joy Nnenna[1], Obasi Emmanuel Chukwubueze[2, *], Achara Obinna Vincent[3]

[1]Department of Electronic and Computer Engineering, University of Nigeria Nsukka (UNN), Nsukka, Nigeria

[2]Department of Electrical and Electronic Engineering, Enugu State University of Science and Technology (ESUT), Agbani, Nigeria

[3]Department of Computer Engineering, Enugu State University of Science and Technology (ESUT), Agbani, Nigeria

Email address:

nnenna.eneh@unn.edu.ng (Eneh Joy Nnenna), engrprofobasi@gmail.com (Obasi Emmanuel Chukwubueze),
Obinna.achara@outlook.com (Achara Obinna Vincent)

*Corresponding author

Abstract: In an era marked by increased interconnectedness, the imperative to safeguard homes and businesses against security breaches has grown exponentially. Recent insights into burglary patterns reveal that conventional security measures are often insufficient to deter intruders. Unlocked doors and windows become vulnerabilities, and even household pets are not immune to the tactics of savvy burglars armed with dog treats. To address these evolving security challenges and provide an advanced and responsive solution, this research endeavours to design and construct a residential intruder alarm system using GSM technology, introducing an innovative approach by employing phone calls for real-time alerts. Leveraging innovative sensors and communication protocols, this system promptly detects and reports unauthorized access, offering users real-time remote monitoring capabilities. The project's objectives encompass system design and integration, reliable intrusion detection mechanisms, remote alerting via phone calls through a GSM module, and rigorous testing and validation. The Wireless Intruder Alarm System, developed, has yielded promising results in addressing security concerns and providing an efficient solution for intrusion detection and notification. Motion detection, the core functionality of the system, has proven highly effective, with the PIR (Passive Infrared) sensor consistently detecting motion within its defined field of view. Upon detection, the system promptly triggers the alarm, providing a swift response to potential intrusions. The significant innovation introduced in this project lies in the utilization of phone calls as a means of alerting users when an intruder is detected. This departure from traditional SMS notifications addresses the drawbacks associated with text-based alerts. Phone calls are inherently more immediate and attention-grabbing, ensuring that users are promptly informed of security incidents. The research highlights the value of this innovative approach by emphasizing the immediacy, audibility, and effectiveness of phone calls, particularly in urgent security scenarios. This ground-breaking integration of phone call alerts enhances the overall responsiveness of the intruder alarm system. It ensures that users receive timely and attention-commanding notifications, thereby facilitating quicker responses to potential security threats. The abstraction from SMS to phone calls represents a significant stride in optimizing notification methods, addressing user preferences, timeliness, privacy concerns, and cost considerations. This research contributes valuable insights into the realm of security systems, paving the way for enhanced and user-centric approaches in fortifying homes and businesses against intrusions.

Keywords: Intruder Alarm System, GSM Technology, Residential Security, Phone Call Alerts, Motion Detection, PIR Sensor, Innovative Sensors, Real-Time Monitoring, Security Challenges

1. Introduction

Protecting homes and companies is crucial in this era of increased interconnectedness [1]. Risks associated with security breaches are high and include damage to property and psychological effects. A prisoner poll uncovered patterns

of burglaries that highlight the weakness of open doors and windows and indicate that silent entrance techniques are preferred by criminals. Contrary to common assumption, most burglaries take advantage of people's absence during the day. A poll also shows that dog treats can deter criminals, and they frequently avoid houses with pets.

Conventional wired alarm systems provide a deterrent, but they are only effective when operated manually or when someone is present to hear the alarm. Wireless intruder alarm systems, which use sensors and communication protocols for instantaneous detection and remote reporting, have evolved as a solution to this constraint [2]. This invention improves responsiveness by enabling users to view sensor feeds remotely and receive real-time notifications.

The wireless intruder alarm system turns homes and workplaces into smart settings by not only setting off local alarms but also speaking with people via voice calls [3]. This wireless technology adapts to the changing security landscape and proven to be adaptable, scalable, and cost-effective. It is useful for both residential and commercial establishments because of its smooth integration with smart home technologies. With this project, security solutions will improve through the design and construction of a wireless intruder alarm system.

2. Related Works

Mohammed et al. developed a security system employing ultrasonic sensor technology, GSM communication, and a microcontroller to detect intruders, sending SMS alerts upon detection [1]. While successful, the limitation of the ultrasonic sensor's directional requirement for wave reflection prompted consideration of the more effective PIR sensor for intruder detection [4]. Similar approaches utilizing SMS notifications were explored by Baballe Ahmad, M. et.al and Somaiya, K. J. They presenting a low-cost intrusion detection system [5, 6].

Recognizing the evolving landscape of security systems in the twenty-first century, Frimpong emphasizes the need for modern security philosophies in homes and organizations [7]. Current options include CCTV, intruding alarm, and gas threshold alarm systems, with remote management capabilities.

In addition to non-optical sensors, Rodelas et al. incorporated optical sensors for intruder detection and recognition using image processing techniques [8]. Their system, coordinated by a programmed ATMEGA16 microcontroller and incorporating AC and DC voltage supplies, successfully detected intruders and sent SMS alerts. However, the inclusion of a camera and algorithm for image transmission is justified only in the absence of pets that could trigger false alarms.

Singh et al conducted a study illustrating various security systems, outlining their pros, cons, mechanisms, and technologies [9]. Emphasizing the importance of continuous home monitoring, Gupta et al. underscore the imperative of security, particularly in the absence of occupants [10]. Eseosa et al. worked-on design and construction of GSM intelligent home security system for real time monitoring of intruders that consisted of intrusion detection sensors, wireless sensors, programmable microcontroller in embedded C language, regulated power supply unit, proteus (circuit simulator), relays, GSM modem, and mobile phone [11]. Akinwumi et al. focused on how to configure a simple home security framework using a PIR sensor (Passive Infra-Red) in light of a microcontroller [12]. Burguera et al. postulated that standard ultrasonic sensors used as range finders are only able to provide tenths of readings per second and have angular resolutions one or two orders of magnitude worse than laser scanners [13]. This makes it fall short to PIR sensor in motion detection. Verma et al. presented a mathematical model of PIR Sensor to enhance its sensitivity [14]. Hanosh et al. investigated the use of Passive InfraRed (PIR) sensors to sense human body motion caused by epileptic seizures during sleep, which makes the body shake and causes the PIR sensor to generate an oscillatory output signal [15].

There is a clear study vacuum about the possible benefits of using phone calls as a notification mechanism because the majority of the literature that has been written about GSM-based security systems has focused on the use of SMS alerts. According to newly available data, phone calls appear to have unique advantages in security situations since they are viewed as more rapid and attention-grabbing. This is especially important when it comes to urgent security notifications. The better qualities of phone calls, such as their immediateness, ability to transmit urgency effectively, and ability to provide auditory alerts, make this study gap noteworthy, particularly in emergency situations. It is emphasized that in order to optimize notification techniques in security systems, extensive study is required to investigate user preferences, timeliness, privacy, and economic concerns in the context of phone calls vs SMS alerts.

3. Method

3.1. Block Diagram of the Work

Figure 1 gives the block diagram of the system. The connection of components in the block diagram represented using arrows between the blocks to show the flow of data or signals.
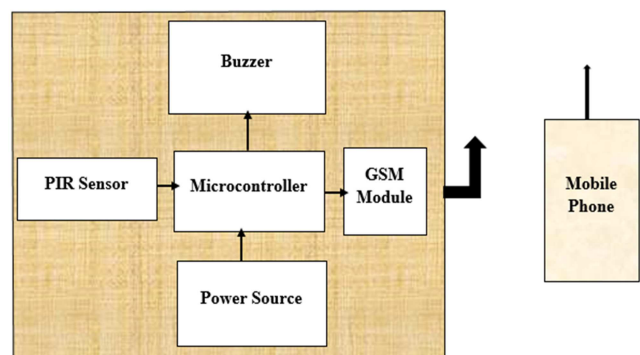
Figure 1. *System block diagram.*

3.2. Connectivity of the Block Diagram

1) Sensor → Microcontroller: An arrow connects the sensor block to the microcontroller block. This arrow symbolizes the transfer of sensor data to the microcontroller for processing.
2) Microcontroller → GSM Module: An arrow connects between the microcontroller and the GSM module block. This signifies that the microcontroller can communicate with the GSM module to send alerts.
3) Microcontroller → Buzzer: An arrow connects the microcontroller block to the buzzer block to indicate that the microcontroller can activate the alarm when necessary.
4) Power source → Microcontroller: An arrow connects the power source block to the microcontroller block to show that the microcontroller is powered by the power source.
5) Network Connectivity: The arrow from the GSM module block shows that information is transmitted from it to a mobile phone wireless.

3.3. Discussion of the Block Diagram

1) Input Sensors: The diagram starts with the input sensors, which is a motion detector sensor (PIR sensors). The sensor is the primary input source for detecting potential intruders.
2) Microcontroller: The sensor interface is connected to a microcontroller, in this case, Arduino board. The microcontroller serves as the central processing unit, responsible for receiving sensor data, making decisions based on programmed logic, and triggering appropriate actions.
3) GSM Module: The GSM module is linked to the microcontroller. It allows the system to communicate with the outside world, typically through SMS messages or phone calls. When an intrusion is detected, the microcontroller can use the GSM module to send alerts to designated mobile devices.
4) Buzzer: In parallel with GSM communication, the microcontroller can activate a buzzer output. This produces an audible alert on-site to notify occupants of the intrusion. The alarm output can also serve as a deterrent to intruders.
5) Power Supply: The system requires a stable power supply to operate continuously. It is a battery pack and power adapter that provides the necessary electrical power.
6) Network Connectivity: The network connectivity enables the GSM module to communicate with a mobile device.

3.4. System Analysis and Design

GSM Module
The SIM800C module is a compact and integrated GSM/GPRS module, which means that it contains various components and circuitry within a single package.

3.4.1. Design Parameters
P_{in}: Power supply voltage to the SIM800C module = 4.2 V

P_{out} : Average power consumption of the SIM800C module during a voice call = 3 W

T_{call}: Duration of a single voice call = 3 minutes (180 seconds)

E_{call}: Energy consumption for making a single voice call
C: Battery capacity = 10,000 joules

I_{sleep}: Current consumption of the SIM800C module in sleep mode = 10 mA (0.01 A)

I_{active} : Current consumption of the SIM800C module during active call = 2 A

3.4.2. Design Equation
1. Calculate energy consumption for making a single phone call:

$$E_{call} = P_{out} x\ T_{call} \qquad (1)$$

$$= 3\ x\ 180 = 540J\ (joules)$$

2. Check if the battery capacity is sufficient to power the GSM module for the specified phone call:

$$C >= E_{call} \qquad (2)$$

10,000 J >= 540 J (In this work, the battery capacity is more than sufficient.)

3. Implement power management strategies to minimize energy consumption when the GSM module is not in use:

Calculate total current consumption:

$$I_{total} = I_{sleep} + I_{active} \qquad (3)$$

$$I_{total} = 0.01\ A + 2\ A = 2.01\ A$$

3.4.3. Power Source Design
Design Parameters
E_{call}= Energy consumption for making a single voice call (joules) = 540 J

C: Battery capacity (joules) = 10,000 J

I_{total}: Total current consumption during active call and sleep mode (amperes) = 2.01 A

T_{call}: Duration of a single voice call (seconds) = 180 s

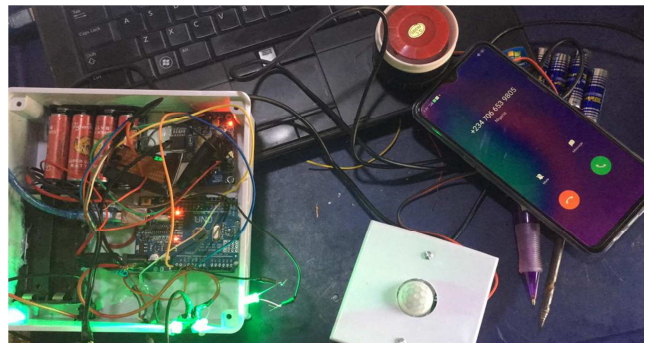P_{in}: Power supply voltage to the SIM800C module (volts) = 4.2 V

Figure 2. *Validation of constructed system.*

4. Results

The Wireless Intruder Alarm System, developed, has yielded promising results in addressing security concerns and providing an efficient solution for intrusion detection and notification.

1) Motion Detection and Alarm Triggering: The core functionality of the system, motion detection, has proven highly effective. The PIR (Passive Infrared) sensor consistently detects motion within its defined field of view. Upon detection, the system promptly triggers the alarm, providing a swift response to potential intrusions.
2) Communication and Remote alerting: The GSM (Global System for Mobile Communications) module successfully facilitates communication capabilities. The system can make phone calls within 5 seconds, when intrusion is detected.

4.1. Discussion

The Wireless Intruder Alarm System project's findings are consistent with the body of knowledge on security technologies and systems in general. The project's successful implementation of GSM-based communication is consistent with other studies that have shown how useful GSM technology is for security systems. Notably, the system's capacity to notify users of security events using GSM communication is practical and reliable, as seen by its ability to swiftly send the system owner a call. The Wireless Intruder Alarm System is consistent with the recent trend in security research, which has been real-time monitoring and alerting. Its capacity to monitor and notify in real-time in response to security risks reflects the goals stated in previous studies. As this experiment has shown, these solutions make sure that consumers are quickly notified of any attacks, which improves security and lowers financial losses.

The Wireless Intruder Alarm System's use of Passive Infrared (PIR) sensors demonstrates the adaptability of sensor technology in security applications. This method shows how sensor technology may be customized for different security requirements, such as defending rural farming regions or residences. It is similar to earlier research on farm intruder detection.

In recent years, cost-effective security technology solutions have drawn attention. The Wireless Intruder Alarm System's effectiveness and affordability are consistent with the idea of economically viable security measures covered in the literature. These kinds of systems might enable more people to have access to cutting-edge security technologies, addressing security issues without putting a heavy financial strain on them. The concept of communal alarm systems covered in earlier studies aligns with the flexibility of the Wireless Intruder Alarm System for home or community protection. These solutions contribute to overall safety by enhancing security and enabling community managers to respond quickly to crises or security breaches. The research's emphasis on improving home security is in line with earlier research that highlighted the drawbacks of conventional locking systems and suggested creative substitutes. The Wireless Intruder Alarm System improves total home security by integrating intrusion detection, automatic warnings, and locking mechanisms, making it a viable substitute for traditional security systems.

4.2. Source Code

```
#include <SoftwareSerial.h>

#define SIM800_TX_PIN 8
#define SIM800_RX_PIN 7
#define PIR_SENSOR_PIN 2
#define BUZZER_PIN 4
#define LED_PIN 13

SoftwareSerial              serialSIM800(SIM800_TX_PIN,
SIM800_RX_PIN);

const char* expectedPhoneNumber = "xxxxxxxxxx"; //
Replace with the specific phone number

bool pirActive = true;
bool alarmEnabled = true;
bool initialDelayDone = false;

void setup() {
 Serial.begin(9600);
 serialSIM800.begin(9600);
 pinMode(PIR_SENSOR_PIN, INPUT);
 pinMode(BUZZER_PIN, OUTPUT);
 pinMode(LED_PIN, OUTPUT);
 turnOffBuzzerAndLED();
 delay(1000);
 Serial.println("Setup Complete!");
}

void makeCall(const char* phoneNumber) {
 serialSIM800.print("ATD");
 serialSIM800.print(phoneNumber);
 serialSIM800.println(";");
}

void triggerAlarmAndCall() {
 Serial.println("Motion detected!");
 if (alarmEnabled) {
 digitalWrite(BUZZER_PIN, HIGH);
 digitalWrite(LED_PIN, HIGH);
 delay(2000);
 turnOffBuzzerAndLED();
 }

 if (pirActive) {
 makeCall(expectedPhoneNumber);
 }
}
```

```
void turnOffBuzzerAndLED() {
 digitalWrite(BUZZER_PIN, LOW);
 digitalWrite(LED_PIN, LOW);
}

void deactivatePIR() {
 pirActive = false;
 Serial.println("PIR sensor deactivated.");
 turnOffBuzzerAndLED();
 alarmEnabled = false;
}
void activatePIR() {
 pirActive = true;
 Serial.println("PIR sensor activated.");
 digitalWrite(LED_PIN, HIGH);
 alarmEnabled = true;
}

void loop() {
 if (!initialDelayDone) {
  delay(10000);
  initialDelayDone = true;
 }

 if (pirActive) {
  int pirState = digitalRead(PIR_SENSOR_PIN);
  if (pirState == HIGH) {
   triggerAlarmAndCall();
   delay(1000);
  }
 }
}
```

4.3. Code Walkthrough

1) #include <SoftwareSerial.h>: This line includes the SoftwareSerial library, which allows serial communication on other digital pins besides the default RX and TX pins.
2) #define SIM800_TX_PIN 8: Defines the digital pin connected to the TX (transmit) pin of the SIM800 module.
3) #define SIM800_RX_PIN 7: Defines the digital pin connected to the RX (receive) pin of the SIM800 module.
4) #define PIR_SENSOR_PIN 2: Defines the digital pin connected to the signal pin of the PIR sensor.
5) #define BUZZER_PIN 4: Defines the digital pin connected to the buzzer.
6) #define LED_PIN 13: Defines the digital pin connected to the LED.
7) SoftwareSerial serialSIM800 (SIM800_TX_PIN, SIM800_RX_PIN);: Creates a SoftwareSerial object named serialSIM800 using the defined TX and RX pins for communication with the SIM800 module.
8) const char* expectedPhoneNumber = "09068169494";: Defines a constant character array representing the expected phone number for making

calls.
9) bool pirActive = true;: Initializes a boolean variable to indicate whether the PIR sensor is active.
10) bool alarmEnabled = true;: Initializes a boolean variable to indicate whether the alarm is enabled.
11) bool initialDelayDone = false;: Initializes a boolean variable to track whether the initial delay has been completed.
12) void setup() {...}: This function is called once at the beginning of the program. It initializes serial communication, sets pin modes, turns off the buzzer and LED, and prints a message indicating that the setup is complete.
13) void makeCall(const char* phoneNumber) {...}: A function to initiate a call to a specified phone number using the SIM800 module.
14) void triggerAlarmAndCall() {...}: A function to handle the alarm-triggering process. It turns on the buzzer and LED, waits for a short period, and then turns them off. If the PIR sensor is active, it calls the makeCall function.
15) void turnOffBuzzerAndLED() {...}: A function to turn off the buzzer and LED.
16) void deactivatePIR() {...}: A function to deactivate the PIR sensor, turning off the buzzer and LED and disabling the alarm.
17) void activatePIR() {...}: A function to activate the PIR sensor, turning on the LED and enabling the alarm.
18) void loop() {...}: This function runs continuously after the setup function. It includes an initial delay and then checks the PIR sensor state. If motion is detected, it triggers the alarm and call functions.

5. Conclusion

In conclusion, the Wireless Intruder Alarm System presented in this work addresses the pressing need for enhanced security in an era of heightened interconnectedness. The research underscores the substantial risks associated with security breaches, emphasizing vulnerabilities exposed by common burglary patterns, such as unsecured doors and windows. Contrary to prevalent assumptions, the majority of burglaries occur during daytime hours, exploiting the absence of occupants. The study acknowledges the significance of pet deterrents and recognizes the limitations of traditional wired alarm systems, prompting the introduction of wireless intruder alarm systems.

The block diagram offers a clear visualization of the system's architecture, outlining the connectivity of essential components. Further analysis delves into the design parameters of the GSM module, ensuring a meticulous consideration of power consumption, energy efficiency, and battery capacity. Results and discussion highlight the system's alignment with existing security technology trends, showcasing the effectiveness of GSM-based communication and real-time monitoring. The use of Passive Infrared (PIR)

sensors exemplifies the adaptability of sensor technology for diverse security applications. Notably, the work's emphasis on cost-effectiveness aligns with the broader trend of making advanced security measures economically accessible.

Conflicts of Interest

The authors declare no conflicts of interest.

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