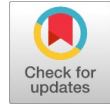


Home Surveillance and Alert System using Raspberry Pi Zero W and GSM Modem with MQTT Protocol



Mekecha Banchigize Bazezew

Abstract: Today's modern era has made it essential for everyone, even for the privacy of their homes, to have controllable, affordable, and easy-to-use security systems. The creation of a cost-effective, straightforward, and feature-rich home security alarm system using a Raspberry Pi Zero W microprocessor and MQTT protocol is discussed in this paper. The proposed system is primarily intended for outlying areas with limited or insufficient network bandwidths. Together with sensors such as a PIR (passive infrared sensor), sound sensor, gas leakage sensor, obstacle/proximity sensor (vibration sensor), fire/flame sensor, GSM module, and a surveillance pi camera, it makes use of a Raspberry Pi Zero W as a microprocessor. [1]. In addition, the system will promptly alert the homeowner through phone calls, SMS, or mail anytime it senses the presence of an intruder or other safety hazards. Hence, anyone who wants to make their space (bank, home, workplace, jewelry shops, and cabins) safe and to protect themselves from theft and infiltration can use this system at a fair price.

Keywords: Raspberry pi, GSM module, PIR motion detector, obstacle sensor, Sound sensor, flame sensor, smoke sensor, pi camera, MQTT protocol.

I. INTRODUCTION

As we all know we are living in IoT world and people living in this era wants to make their life simple and modern. therefore it's really important to develop a system which can be controlled remotely. Currently Security is becoming a very crucial concern as the probability of unauthorized entry and theft are increasing dramatically. It is estimated that up to 2025 there will be near about 70 billion internets enable devices available. therefore Safety from intrusion, theft, fire and gas leakage are the necessary requirements for any kind of home security system [2][3].

Although There are lots of security systems that are already available for home security, they are much expensive and difficult to use and manage .so in this paper propose a system which is affordable, simple and effective Raspberry Pi based surveillance and alert system to home through internet, which notify the user through an email, phone call, SMS.

II. RELATED WORK

Nowadays, it is becoming obvious that studies use microcontrollers and sensors to develop home security systems. However, most of them have limited features and none of them comes as integrated system. Additionally, they are very expensive and sophisticated.

"Design and implementation of an IoT-based smart home security system" presents the design and implementation of a smart home security system that uses IoT technology. The system is accessible through a mobile application that allows the user to arm/disarm the system, view live camera feeds, and receive alerts in case of a security breach. They evaluated the performance of the system and demonstrated its effectiveness for securing homes [4].

"An IoT-based smart home security system using Raspberry Pi" describes the design and implementation of a smart home security system that uses Raspberry Pi and IoT technology. The authors develop a mobile application that allows the user to control the system, view live camera feeds, and receive alerts in case of a security breach. The authors evaluate the performance of the system and demonstrate its effectiveness in securing a home. [5]

"Smart home security system based on Raspberry Pi and IoT" presents the design and implementation of a smart home security system that uses Raspberry Pi and IoT technology. The authors develop a mobile application to control the system and receive real-time alerts in case of a security breach. The authors evaluate the performance of the system and demonstrate its effectiveness in securing a home. [6]

"An intelligent home security system using Raspberry Pi and IoT" presents the design and implementation of an intelligent home security system that uses Raspberry Pi and IoT technology. The system is designed to monitor and secure a home by detecting and reporting any security breaches. The authors evaluate the performance of the system and demonstrate its effectiveness in securing a home. [7]

"Theft detection system using PIR sensor" this paper proposed a home security for the theft by implementing smart surveillance system using raspberry pi and PIR sensor. The project is designed as a smart surveillance system capable of capturing video, images, recording it and transmitting to a mobile phone. It is encrypted and authenticated on the receiver side, so that it will offer only the owner so that he could view the details. Necessary action could be taken within some part of time in the case of any burglary activities takes place.

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This paper is limited to PIR sensor and there is no email notification and doesn't use MQTT protocol too [8] [9].

"IoT based home automation and security system" The aim of this paper is to design the secure Home automation system which is accessed from global position. In this proposed system raspberry pi is used as gateway between web dashboard and actual system devices as well as sensors. The author uses MQTT protocol for faster communication [10].

"Motion activated security camera using Raspberry Pi" mainly they focus on the origination and execution of an inclusive continuous home security framework that is shrewd and totally deals with home security. This home security framework is named as raspberry pi (RPI) and open CV with Harr cascade [11].

"Raspberry PI Based Advanced Security System Using IOT" "this paper propose a surveillance system is to notify the user whenever there is human interference in the surveillance area Using PIR sensor .in this proposed system The presence of motion notifies the user by sending short message service (SMS) through GSM Module [12].

"Using raspberry Pi and GSM survey on home automation" The aim of this Paper is to develop a home automation application using Raspberry Pi and GSM. Programming has been developed in Python environment for Raspberry Pi operation [13].

"IoT based Smart Home: Security Challenges, Security Requirements and Solutions" In this paper, security threats are detected by making several scenarios and evaluate the impact of these threats on a smart home environment. The paper also studied the recent existing literature of security to identify techniques for prevention against security attacks and set security goals for the smart home using these techniques [14].

III. PROPOSED SYSTEM

This paper proposed an idea of smart home security and alert system using sensors data as an input and processed using python code using raspberry pi zero Was microcontroller. This integrated system contains five sensors to make the security system more effective. As you can see from the proposed architecture below all the five sensors including the pi camera and GSM module are interfaced with the raspberry pi zero w. in addition to this efficient power supply is needed to power the raspberry pi and the GSM module .the recommended voltage for the raspberry pi is 5v and for GSM it is 9v-12v.f one of the sensors detect any interference, the system will automatically trigger alarm and simultaneously, the GSM module sends an SMS and make a phone call to the homeowner so that he/she can make the necessary actions. In addition to this the system also notifies the user through email alert and packets are transmitted using MQTT protocol. This system is convent for low- or middle-income households or countries. The whole system design is shown in Fig.3.1.

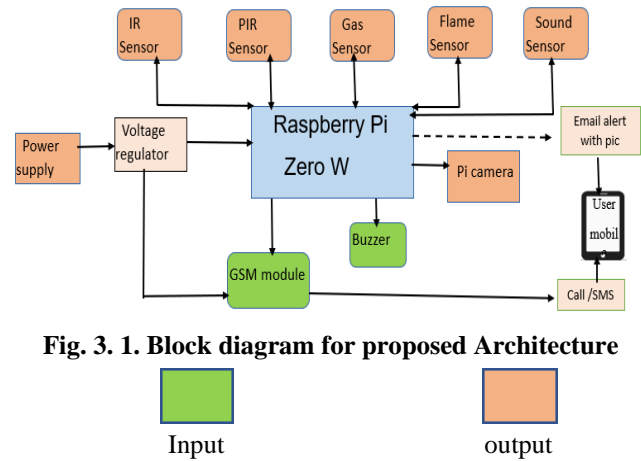


Fig. 3. 1. Block diagram for proposed Architecture

Generally, the proposed prototype consists of 4 features: -

1. Sending Email alert to authorized mail using SMTP
2. Packet transmission using MQTT protocol
3. Make call and SMS via AT commands
4. Buzzer alert system

3.1. Sending Email alert to authorized mail using SMTP

Let say the owner is not in his house and an intruder get into his house then there is no way to know what's happing in his home. But this prototype will notify him through the burglary action. In this prototype all the five sensors have their own functionality and detection range. Therefore, if one of the sensors detects unauthorized action in their range then the User will be notified by email alert. this mail have a subject and image attached to it. so that the user will be able to see what's happening in the house.

The email is sent through a push protocol which is SMTP (Simple Mail Transfer Protocol) to already registered mail ID. SMTP is an application layer protocol and is an Internet standard for email transmission. Nowadays the use of this protocol is increasing dramatically because of its features. Therefore, the owner of the house can receive email alert about what is happening in his house wherever he is, and he can take the necessary measures.

3.2. Packet transmission using MQTT protocol

MQTT is extremely lightweight communication protocol that uses publish subscribes principle this protocol is the best solution for connecting constrained and low bandwidth devices in remote location.

Basic concepts of MQTT protocols are: -

A. Publish/subscribe

The publisher is the one who send the message to the receiver. and the subscriber is the one who receive the message which is sent by the publisher. here the main concept is the publisher/sender sends the message without prior knowledge of the subscriber/receiver. Likewise, subscribers show their interest in one or more topics and they only receive the message that they want without knowing which publisher sends the message.

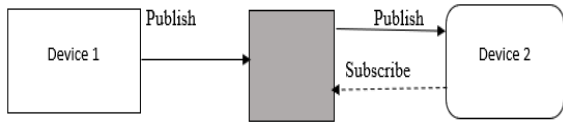


Fig. 3.2. Publish/subscribe model

Device 1 publishes on a topic device 2 is subscribed to the same topic in which device 1 is publishing in device 2 receives the message.

B. Messages

Message is one of the basic concepts in MQTT which is the information exchanged between the devices command or data.

C. Topics

Topic is are generally Interest for incoming messages and specify where you want to publish. They are represented with strings separated by slash “/” slash indicate the topic level.

D. Broker

Broker is the main component of MQTT protocol. Based on the how it’s applied, a broker can manage many MQTT clients. It receives all the messages and filters them and publishes the message to all subscribed clients. Brokers should be: -highly adaptable, integrable into corporate systems, easy to manage and fault tolerant I.e. this paper used a pubic broker.

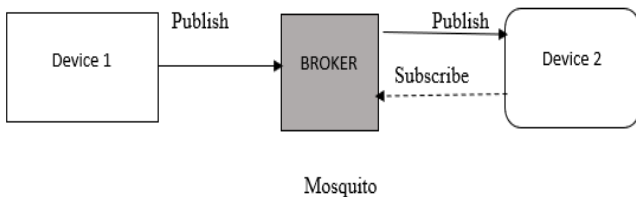


Fig.3.3. Publish/Subscribe model with broker

3.3. Sensor triggering via AT commands

Triggering sensors via AT command is another main feature of this paper. GSM is used to fulfill this task. GSM is a digital cellular network system for voice and data communication and it operates in different frequency bands, 900MHz and 1800MHz are the common ones.

A GSM network comprises of many functional units and it can be broadly divided into:

- A. The Mobile Station (MS)
- B. The Base Station Subsystem (BSS)
- C. The Network Switching Subsystem (NSS)
- D. The Operation Support Subsystem (OSS)

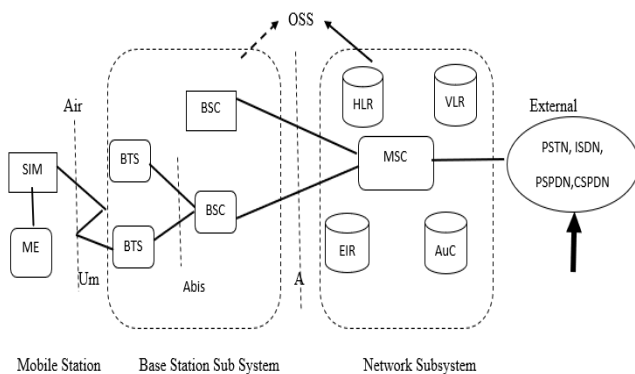


Fig.3.4. GSM Architecture

At (Attention) Command

These commands are used to give instruction and control the GSM modem. The name AT command is given to modem commands because each command begins with “AT” OR “at”. Some of the most common SMS related commands are listed in Table below.

Table 3.1. SMS-Related Commands

AT Command	Command Function
ATD	Dial
AT+CMGS	Send SMS
AT+ CMSS	Send SMS Message from Storage
AT+CMGL	List SMS Message
AT+CMGR	Read SMS Messages

3.4. Buzzer Alert System

Buzzer alert is the last but not the list feature of the proposed system. Before the owner receives any mail or phone calls and SMS notification when the sensors detect any unauthorised action in the house the system immediately trigger alarm.

IV. HARDWARE COMPONENT DESCRIPTION

The proposed security and alert system consist of the following hardware components.

A. Raspberry pi zero W

Raspberry pi is the advanced version of the microcontrollers. among the raspberry pi family raspberry pi zero W is the one which has built in wifi and Bluetooth. this single board computer is used in this proposed system because we can have all the features that the other raspberry pi families have but its available at lower price which is the main goal of the project. Raspbian OS is used as an operating system.

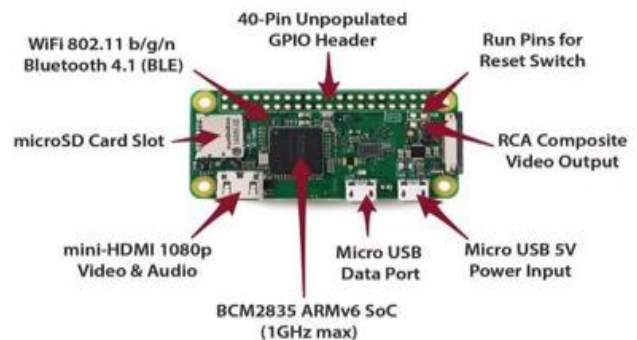


Fig.4.1. Raspberry pi zero W

B. PIR sensors

A passive infrared sensor (PIR sensor) is one kind of motion sensor that measures infrared light which is emitted from human beings. most security systems uses this sensor because they are easily accessible, affordable, needs low power to operate, easy to work with and easily compatible with raspberry pi zero w. Therefore when the PIR sensor detects the presence of human being in its detection range it will generate the output. The output will depend on the program written in python.



Detection range for PIR sensor is 6 meter and it needs 5V power supply and output voltage is 3.3V. Sensitivity range of this sensor is adjustable.



Fig. 4.2. PIR sensor

C. Gas sensor

This sensor is very convenient for detecting gas leakage like CO, smoke, LPG and propane. Most home automation and safety systems use this sensor because it's stable and long life in addition it has fast response and high sensitivity. The detection range is so wide so its preferable. it works on 5v.



Fig. 4.3. Gas sensor

D. Obstacle/Proximity Sensor

Obstacle sensor/proximity sensor is preferable for detecting any object near to the sensor without any physical contact. The sensor works based on the infra-red ray reflected from the objects. Obstacle sensor has good performance and long-term functionality because there is no physical interaction between the sensor and the object to be sensed. this sensor works on 5v and 3.3v input and its detection range is between 10 and 12cm.



Fig 4.4 IR /Obstacle Sensor

E. Sound sensor

Sound Sensor can detect the sound intensity of the environment amplifier. Sound sensor is used to detect whether there's sound surround or not and this module's output is Analog. The sound sensor can measure noise levels in decibels (dB) at frequencies around 3-6 kHz where the human ear is most sensitive. it works on 3.3v to 5v voltage.



Fig 4.5 sound sensor

F. Flame sensor

Flame /fire detector is a sensor which basically used to detect the presence of fire or flame. The working principle of this sensor makes it more accurate and faster response rate than other sensors like smoke detectors. Even though fire /flame sensor is used to detect flame, it can also be sensitive to normal light. The detection range for this sensor is between 760nm and 1100nm. This range is adjustable based on the system functionality. Flame sensor works on 3.3v and 5v effectively.



Fig 4.6. Flame sensor

G. Pi Camera Module

Pi camera module is used to take picture whenever needed .in this system when someone or other safety issues are detected by the corresponding based on the python code. The captured image then used as evidence whenever needed. The pi camera module has 5MP resolution and able to take a picture and record a video but not sound.

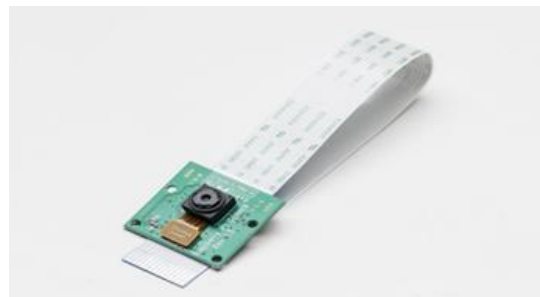


Fig 4.7 pi camera

H. GSM

The module allows the system to communicate over the mobile network through calls and SMS. By using this modem, the system will make audio call and send SMS to victim through a mobile network to take appropriate measure and the owner can read the message and take the necessary actions as soon as possible.



The maximum power supply for this module is 12v and 2amp current. The proposed system uses Universal SIM900A_GSM_Modem which has Configurable baud rate from 1200-115200 through AT command.



Fig.4.8. Universal SIM900A_GSM_Modem

I. Buzzer

The final hardware component of the system is a buzzer or beeper, which is utilized to generate a sound signal. This device is commonly used for a wide range of applications, such as alarms and timers. Within the proposed system, the buzzer is activated in the event of an intrusion or the occurrence of a safety-related incident, such as fire, sound, gas, or obstacles within the home. These events are detected by the PIR sensor, fire sensor, sound sensor, gas sensor, and obstacle sensors, respectively. Once detected, the buzzer is triggered to generate an alarm, thereby notifying the owner of the home of the potential threat. Overall, the incorporation of the buzzer into the system represents an essential component of the overall safety strategy, providing a highly effective means of alerting individuals to potential danger within their home.



Fig.4.9. Magnetic active buzzer alarm ringer

V. PRINCIPLES OF OPERATION

This system incorporates five different sensors, specifically a PIR sensor, fire sensor, gas sensor, sound sensor, and an obstacle (proximity) sensor, that are interfaced with a Raspberry Pi Zero W. In order to enhance the security capabilities of the system, a GSM module and Pi camera are also integrated. As a result, in the event of an intrusion or other safety-related occurrence, the system will immediately activate an alarm. Upon alarm activation, the GSM module sends an SMS and makes a phone call, followed by an email alert that includes a captured image. By subscribing to the relevant topic, users can also remotely access the MQTT App to monitor and observe any activity occurring within their home. Overall, this integrated security system offers an effective and comprehensive approach to home security that leverages a variety of advanced sensors and communication

technologies to ensure the safety and protection of individuals and their property.

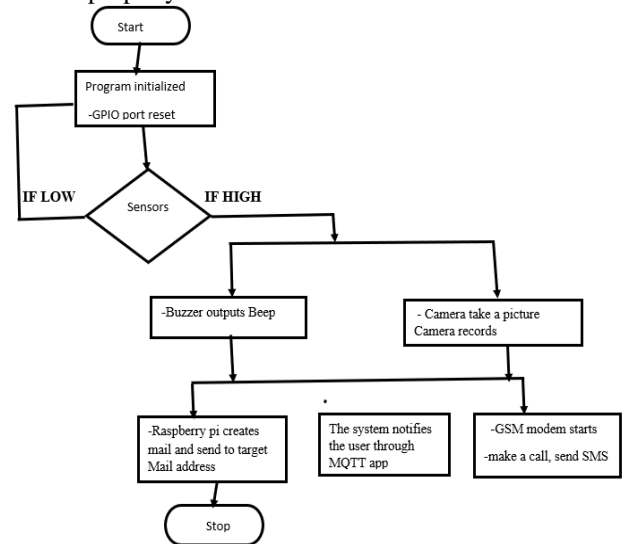


Figure 5.1 illustrates the entire working procedure of the system.

VI. RESULT

The entire system prototype has been successfully implemented, as depicted in Figure 6.1 which showcases the interface of the sensors and GSM module. The system leverages a PIR motion detector sensor, sound sensor, gas leakage sensor, obstacle/proximity sensor (vibration sensor), fire/flame sensor, GSM module, and Pi camera to enable the detection and reporting of potential intruders and other safety issues. In the event that the system detects the presence of an intruder or other safety-related issue, the victim is immediately notified via email (as illustrated in Figure 6.2). Additionally, the designated person is notified in real-time via a phone call or SMS through the GSM module (as demonstrated in Figure 6.3). Furthermore, users can also receive notifications through the My MQTT App, as shown in Figure 6.4. The system is designed to operate seamlessly, allowing for the rapid and efficient detection and reporting of potential threats to the safety of the home and its occupants. The flow diagram of the system's working procedure is depicted in Figure 5.1.

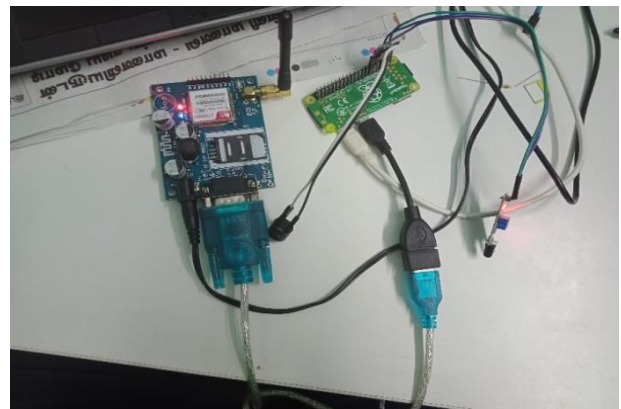
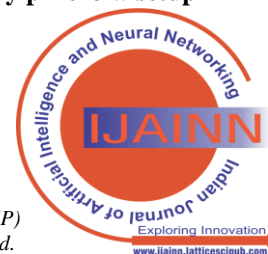


Fig. 6.1. Raspberry pi zero w setup



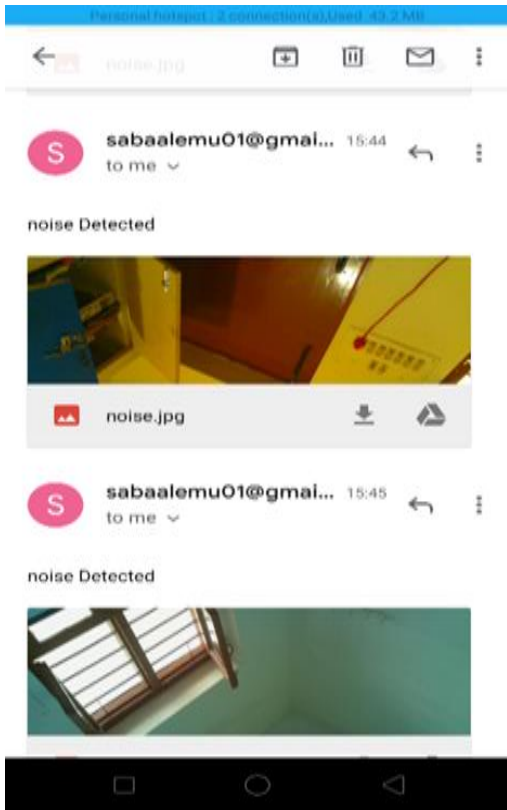


Fig.6.2. Email received by the owner

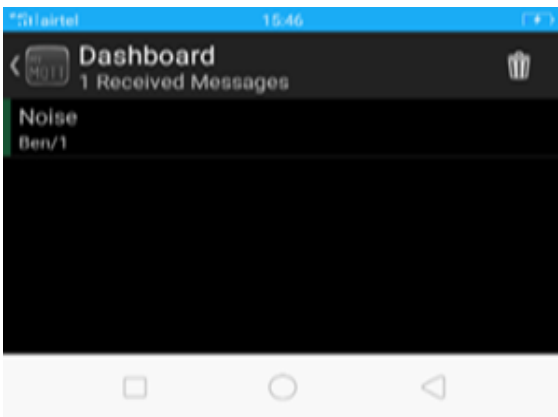


Fig 6.3: message received through MQTT

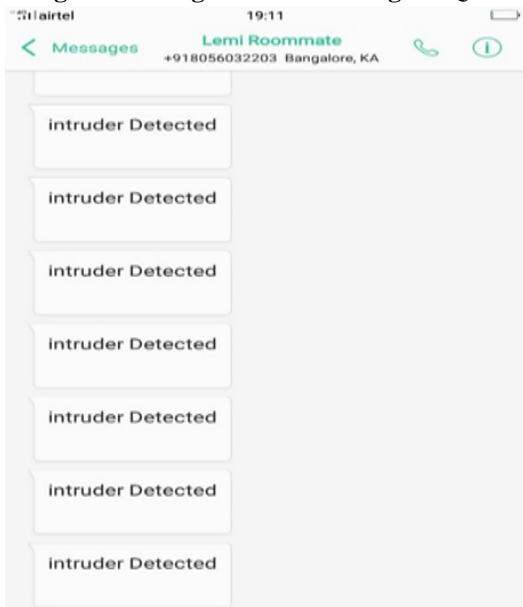


Fig. 6.4. Message received by the owner

IV. COMPARISON OF THE PROPOSED SYSTEM AND THE EXISTING SYSTEMS

The proposed system has several features and is affordable to anyone. I have read many systems which are related to home security but most of them are so costly do not have adequate security and alert like mine. The Comparison between the existing systems and the proposed system is clearly mentioned in [Table 7.1](#).

Table7.1. Comparison Table of Existing Systems

System name	Motion Sensor	Gas sensor	Sound sensor	Fire sensor	Object sensor	GSM	MQTT
Theft detection system using PIR sensor	Yes	No	No	No	Yes	Yes	No
Design and Implementation of Security Systems for Smart Home based on GSM technology	Yes	No	No	No	No	Yes	No
IoT based home automation and security system	Yes	Yes	No	No	No	No	Yes
Motion activated security camera using Raspberry Pi	Yes		No	No	No	No	No
Raspberry Pi Based Advanced Security System Using IOT	Yes	No	No	No	No	Yes	No
Using raspberry Pi and GSM survey on home automation	Yes	No	No	No	No	Yes	No

V. CONCLUSION

The Raspberry Pi has become a popular and versatile platform for developing IoT-based systems for home security, and this work has demonstrated a practical and sophisticated security and warning system utilizing various sensors. The Raspberry Pi Zero W used in this project offers an affordable and user-friendly alternative to traditional home security systems, with the ability to adapt to diverse security requirements. The proposed prototype meets the needs of surveillance in a wide range of settings, including offices, storage facilities, and bank lockers, providing users with the ability to remotely monitor the security of their property through notifications generated by the connected application. Overall, utilizing a Raspberry Pi in home security systems is a reliable and effective way to enhance the security of both residential and commercial buildings.

DECLARATION

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Conflicts of Interest/ Competing Interests	No conflicts of interest to the best of my knowledge.
Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	I am the sole author of the article.



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