Real-Time Smart Monitoring System Based-IoT Applications

Laith Farhan[1], Ali Abbood Khaleel2,Waled Gheth[3], Waqas Saad[4], Wurood Kadhim Yas[4], Ahmed Hussein Dawwd[4] and Sajjad Khalaf Hussein Ali[5]
[1]College College of Engineering, University of Diyala, 32001 Baqubah, Iraq
[2]Department of Computer Engineering Techniques, Bilad Alrafidain University College, 32001 Baqubah, Iraq
[3]School of Computing and Engineering, University of Huddersfield, HD1 3DH Huddersfield, United Kingdom
[4]University of Diyala, 32001 Baqubah, Iraq
[5]College of Islamic Sciences, Al-Iraqia University, 10001 Baghdad, Iraq
l.farhan@uodiyala.edu.iq, W.gheth2@hud.ac.uk, waqas_saad_ecc@uodiyala.edu.iq, sajjad.kh.hussein@aliraqia.edu.iq

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Abstract: In recent years, crime rates in the world are increasing at an alarming rate due to theft cases based on the police reports. Usually, thieves run away because of delay in action which increases the risk of being caught. Thus, this paper introduces smart IoT-based security system to detect and deter thieves. The system includes microwave motion sensors and other sensors, all connected to the microcontroller (e.g. ESP32). The microcontroller is responsible for processing and transmitting the data to the cloud infrastructure via Wi-Fi technology. The user then can remotely control and monitor the proposed system through a devoted mobile application. The proposed system is also provided with real-time alert notifications. When a sensor motion is triggered, then the control unit is active and sent an instant notification to the user on the smartphone. Furthermore, the device can also be programmed to activate a loud alarm, switch on lights thus effectively scaring away potential thieves. The proposed system allows for flexible customization, remote arming/disarming, and also integration with other smart home devices. This device is designed to be energy-efficient, plug and play, and low-cost, providing accessibility for diverse users looking for a modern and effective security solution. The comparative evaluation confirms the positive impact of the present work as compared to other related techniques existing in the previous works. We reveal that the proposed system achieves less energy consumption, latency, and cost. This successfully enhances the performance of the overall system and product success.

1 INTRODUCTION

In recent decades, the police have notified an increase in the number of theft offences, mainly driven by a substantial rise in homes, manufacturers, companies, shoplifting, etc. According to the police reported, the crime reached the highest level in the last years [1]. Security systems are very crucial to protect people, property, vandalism, and damage, and reducing losses [2]. Therefore, a smart security system provides advanced features for example, remote monitoring via smart devices, integrating with other smart devices, 24/7 protection, is required.

A smart home security system is a communication of interconnected of devices, such as alarms, surveillance, and sensors, that link together to control and protect a home remotely via internet using mobile application or other devices [3]. It includes software and hardware to provide features such as motion detection, real-time alerts, remote access. These can be helped in the disasters and specially for the human dangerous like flooding, earthquake, fire, theft, etc. Most of smart security devices are available in the markets can be categories into two types: locally and remotely security systems [4]. Figure 1 shows locally and remotely monitoring systems scenarios. The local security systems install in-home to achieve home automation and are not controlled remotely by a central station. Thus, this system has restriction of limited access range. It requires someone to contact the emergence services or take appropriate action i.e. contact fire department, police, provide maintenance, etc.

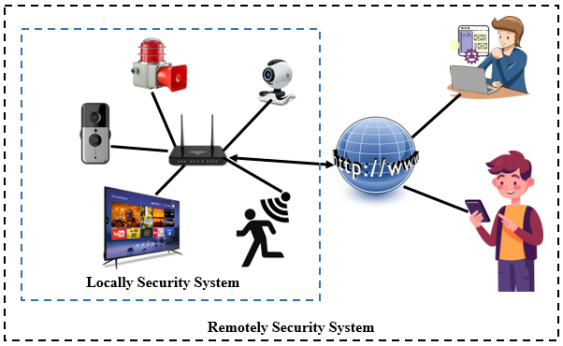


Figure 1: Introduces locally and remotely system scenarios.

However, remotely security systems allow users to control, access, monitor oversea security equipment such as sensors, camera from a remote distance, typical via cellular networks or internet connection by using web interfaces or mobile application [5], [6]. Therefore, smart homes should provide safety and security features to alert the residents from accidental, natural or human dangers.

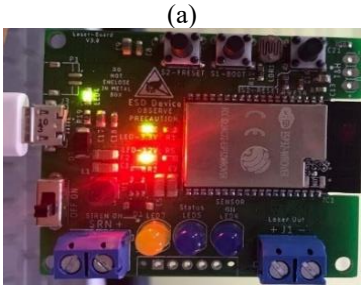
A modern security system should identify intruders trying to enter a house/building and then alert the homeowner to the break-in or any suspicious activity. Ideally, the system would also prevent the intruder from entering the house and gather evidence of the attempted intrusion. Up to now, several studies have introduced modern IoT security systems. For example, authors in [7] designed a security system that can alert the user by sending notification on their smartphone if robber break-in. The user will also start or stop the proposed system remotely using just his device. The proposed work uses Raspberry Pi and Atmega 328 microcontroller and various sensors like PIR motion sensors to detect any movement in the specific area. Also, the proposed system includes a siren to alarm the user and notification message is provided. Another study [8] introduced home security system based IoT applications. The proposed system integrated with ESP32 microcontroller, PIR motion sensor, and sound sensor (ky-037 model). This work can detect suspicious sound or movement near to the door and then sending the real-time alert to the Blynk application on the user smart device. Similarly, authors [9] introduced smart surveillance system by using PIR and temperature sensors. The proposed system is used to notify and detect the intruders accessing into the buildings. This work reveals a smart home automation system for theft detection. In different study [10], authors presented security system based IoT technique to detect fire and motion movement. This system is designed in real-time connection and provided the emergency alerts messages. The authors are used PIR, smoke, and temperature sensors for motion, fire, and climate detection respectively. Most of these studies above used PIR sensors. The PIR sensors are sensitive to detect human or animal movement by sensing infrared radiation emitted depend on local temperature changes in the detection area. This means their efficiency and performance can be affected. There is also a little research about security home system. Realizing the gap in the extant literature, more research is needed for motion detection systems based IoT technology. To our knowledge, a few research have been carried out on motion detection. To address these gaps, our proposed work is a real-time monitoring based-IoT security system. The proposed system is aimed to design and implement IoT device integrated with the ESP32 microcontroller, two types of microwave radar motion detection (RCWL-0516, HFS-DC06 5.8G) respectively, temperature and humidity sensor, siren, and light. The microwave motion sensors are better for outdoor, large and complex areas, this because these sensors are less affected by temperature and detect through obstructions. This work is capable to detect intruder's movement and send the real-time notifications to the Blynk app on the user smartphone.

The manuscript is organized as follows: Section II describes the aim and architecture of the proposed system model. Also, in this section, the hardware design, and programming system, and testing the performance system and evaluation and discussion are introduced. Section III presents the results and discussion for the proposed work. Finally, we conclude our work in Section IV.

2 SYSTEM MODEL

The objective of this work is to design and implement an IoT movement detection system that integrate with central controller and communications units for connectivity. When a device senses motion, then it sends the signal to the control unit, this triggers actions such as activating an alarm and sending notification message to the users on their smartphone via cloud services. This approach is included three main parts: 1) Hardware design. 2) Programming system. 3) Testing performance system and evaluation. Figure 2 reveals the overview of the proposed device. The data flow diagram for the proposed technique reveals how the device is worked and data senses, transmits from the device to user via internet and alert user, see Figure 3.

(a)



(b)

Figure 2: Overview of the prototype system: a) Schematic IoT motion detection, b) The printed circuit board of the proposed system.

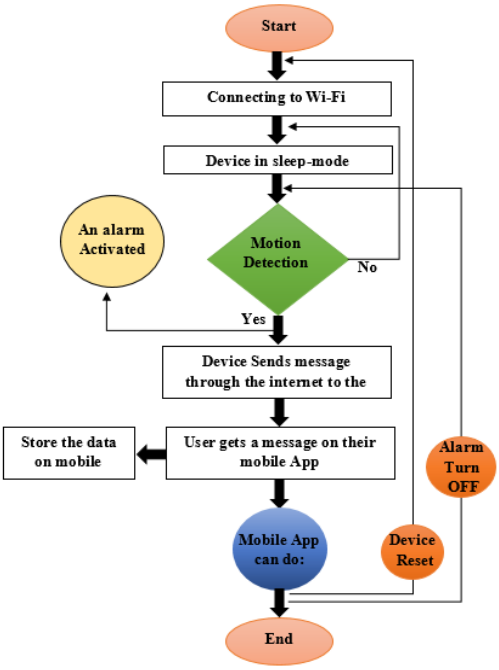


Figure 3: The data flow diagram for the proposed system.

2.1 Hardware Design

The proposed prototype system includes the important of physical components such as microcontroller, sensors, and electronic elements i.e. diodes, capacitors, resistors, transistors, etc. Thus, we provide a brief explanation of each part separately. Figure 4 shows the important physical components of the proposed system.

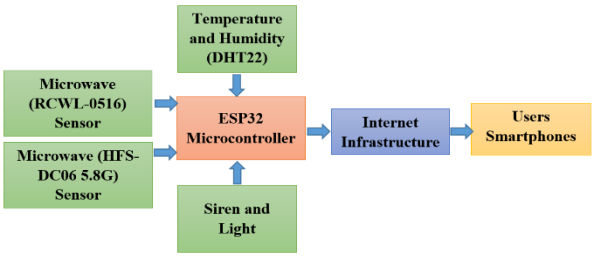


Figure 4: The proposed system architecture.

2.1.1 The ESP32 Microcontroller

The ESP32 is an energy-efficient and low-cost device that cooperates with Bluetooth 4.2 and Wi-Fi 2.4 GHz 802.11b/g/n capabilities [11], [12]. It contains 48 pins with multiple functions; however, some pins cannot be used. The ESP32 is an excellent component for IoT applications. The ESP32 presents various power saving modes such as modem sleep, light sleep and deep sleep. The modem sleep mode, the ESP32 is fully power. While the light sleep makes the CPU state active but disables the Bluetooth and Wi-Fi radio to reduce the energy consumption. This allows the ESP32 to resume their tasks almost instantly upon waking. However, in the deep sleep, the CPU is fully power down and most peripherals, see Table 1.

So, the study choice ESP32 microcontroller because it is cheaper, low-power consumption and tiny sensor nodes than other models and still suitable for our purpose. The ESP32 is used in this research as an example of IoT application to gather and collect the data from three sensors, then process and dispatch the data to the final destination. Figure 5 shows the ESP32 board.

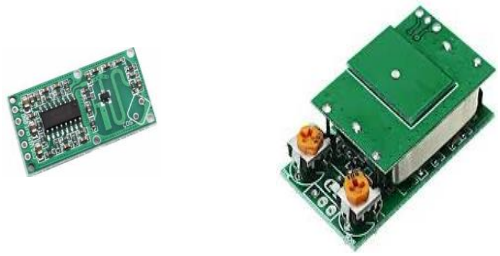
Table 1: shows various power saving modes of ESP32 kit [13].

Power mode	Active Modem-sleep		Light-sleep	Deep-sleep	Hibernation
Sleep pattern	Association sleep pattern			ULP sensor-monitored pattern	
CPU	ON	ON	PAUSE	OFF	OFF
Wi-Fi/BT basedband & radio	ON	OFF	OFF	OFF	OFF
RTC memory & RTC peripherals	ON	ON	ON	ON	OFF
ULP co-processor	ON	ON	ON	ON/OFF	OFF

Figure 5: The ESP32 board [12].

2.1.2 Motion Detection Sensors

Motion detection sensors are electronic devices that design to sense nearby motion or any changes in the surrounding environment [13], [14]. This research is used microwave sensor instead of PIR sensor. Typically, this because the microwave sensors have larger sensing range compared to the PIR sensors. Also, the microwave sensors prevent false alarms from non-human sources. Therefore, we use two types of microwave motion sensors. 1) The RCWL-0516 [15] is a doppler radar microwave motion sensor which is an alternative to PIR motion sensor. This sensor is low-power energy consumption and maximum sensing distance is approximately ($2 \simeq 7$) meters. This sensor is used indoor area such as room, office, store, garage, etc. 2) The HFS-DC06 5.8G [16] is the same of the above motion sensor however, it can cover and sense long range area ($3 \simeq 20$) meters. This type of sensor is the best choice for the outdoor detection movement human body. Figure 6 shows the proposed motion sensors. A) The RCWL-0516 microwave motion sensor. B) The HFS-DC06 5.8G microwave motion sensor.



(a) (b)

Figure 6: Microwave motion sensors: a) RCWL-0516 [13], b) HFS-DC06 5.8G [14].

2.1.3 Temperature and Humidity (DHT22) Sensor

The DHT22 sensor is a low-cost and low energy consumption digital humidity and temperature sensor [17]. This sensor measures the temperature and humidity of an environment simultaneously. It is compatible with ESP32 microcontroller. It consists of three pins ground, voltage, and data. Figure 7 reveals the proposed sensor.

Figure 7: Temperature and Humidity Sensor [17].

2.1.4 Alarm Device

It is an electronic device that designed in order to generate a loud, attention-grabbing sound and light that can travel long distances [18]. Figure 8 shows the siren device.

Figure 8: Siren device [18].

2.2 Programming System

After the hardware was implemented and realized to be working correctly, the Arduino 1.8.19 platform was installed on the Windows 10 to program the ESP32 kit. We used C++ language to program the proposed kit. The IoT device collected the data from the surrounding environment and then send it to the user through the internet. The user used an App to receive the data and also monitor the IoT device remotely. This app is connected to the Firebase that offers backend services such as file storage, user authentication, and database. Also the Firebase platform is integrated for a variety of applications like JavaScript, iOS, Android, Node, etc.

2.3 Testing Performance System and Evaluation

The IoT applications have widely applied and used in many fields, thus, various smart devices are used for tracking, controlling, monitoring activities [19]. These smart devices are triggered by detecting an

action occurred like glass breaking, motion, a door or window opening, etc. After these triggers, the smart device sounds an alarm and sends a notification message to the users on their mobile. Furthermore, false alerts can also happen due to power interruptions, wireless interference, low batteries, etc. Thus, this paper aims to design and implement real-time monitoring security system based IoT application. This system is proposed to detect human motion by transmitting low-power microwave pulses and then measure the doppler shift in the reflected waves. So, these waves collide a moving object, thus, the frequency changes. This means the microwave sensor indicates movement and this in turn, can send an alert to the user on their smart home and trigger other actions such as sounding alarm or turn light on.

Here, the ESP32 acts as the gateway, connecting the sensors to the internet. The proposed device includes two types of microwaves RCWL-0516 and HFS-DC06 5.8G sensors respectively. These sensors used for detecting human movement for short- and long-range distance, see section (2.1 Hardware Design) for more details about these sensors. In this project, the DHT22 sensor is included to sense the temperature and humidity inside the building. Moreover, the siren device is included to produce a loud sound and light and warm user to an emergency. The data is collected by two microwave sensors and forwarded to the ESP32 which uses its WiFi built-in to connect and transmit the gather data to the user application on their smartphone. The proposed system is energy efficiency which means consuming less energy to do the same job done. Thus, most of the time, the proposed device is in light-sleep, unless there is movement in the coverage area by motion sensor. In this case, the device becomes active and sends an alert notification to the user on the smartphone, in addition, the siren device is activated. Furthermore, the DHT22 is sent the value when there is changed in the temperature and humidity value. This means that the device is in the light sleep mode and thus, reduces the energy consumption.

On the monitoring side, in case any event or movement is detected, the users get notifications on their mobile. The users can check the system status, device, sensors or siren for any movement detection and then contacts the relevant authorities for that purpose. Also, the user can turn ON/OFF the siren, rest or shutdown the device. For example, the user gets an alert if any movement is detected around sensor sensed. Also, the user can open the mobile app and check the status of the system and check the house temperature and humidity during real-time communication.

3 RESULTS AND DISCUSSION

The proposed system is placed in the area of interest. The embedded IoT device is run for 24 hours. The motion sensors are waiting any unusual activities to sense and collect data from the area and then transmit it to the user for real-time monitoring. The sensed data is collected from the user smartphone and used for further analysis. The DHT22 sensor is programmed to measure and record any changes happened in both temperature and relative humidity in the specific area. Otherwise, the proposed device is in light sleep mode to reduce energy consumption. Table 2 introduces some of the collected data from the proposed system.

Table 2: Data collected.

Date & Time	Motion	Temperature	Humidity	Siren ON	Energy used
20/08/2025 06:00	0				263
20/08/2025 06:05	0	40	60		265.5
20/08/2025 06:10	0				263
20/08/2025 06:15	0				263
20/08/2025 06:20	0				263
20/08/2025 06:25	0				263
20/08/2025 06:30	0				263
20/08/2025 06:00	0				263
20/08/2025 06:35	0				263
20/08/2025 06:40	1			1	563
20/08/2025 06:45	0				263
20/08/2025 06:50	0	41	61		263

Figure 10 shows the motion detection chart that displays a binary signal (1,0) detect or not detect motion respectively. From this figure and during the 24 hours' test, the motion sensors was detected eight times of detection movement in the home. This means that only the eight-value sent to the user and thus, this reduced the energy consumption by the proposed system. While Figure 11 shows the siren values wake up when the motion detection happened.

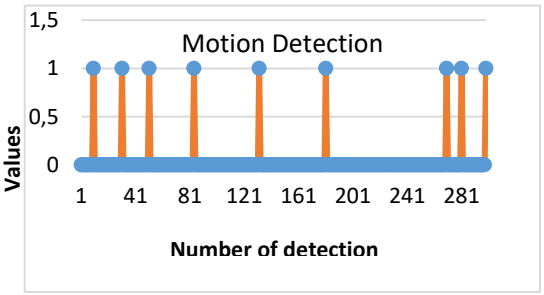


Figure 10: Motion detection values.

Table 3: Comparison between the proposed system and existing motion detection systems.

	Proposed system		Reference [7]	Reference [10]
	RCWL-0516	HFS-DC06 5.8G		
Cost	High	High	Low	Low
Sensing range	5-7m	3-20m	3m	3m
Angle sensing	360°	360°	<100°	<100°
Energy usage	2.8mA	3mA	2 mA	2 mA
Latency	2 second	2 second	5-200 second	5-200 second
Affect by surrounding	No	No	Yes	Yes

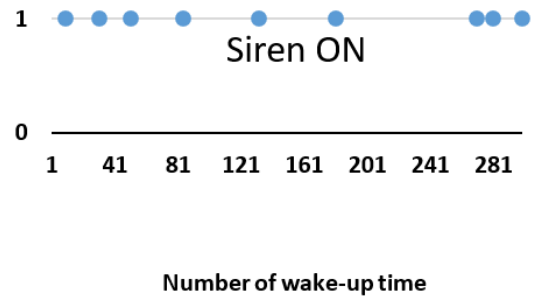


Figure 11: demonstrates the siren wake up when the motion detection happened.

Figure 12 presents the energy consumption used by the proposed system during the test. The device consumed (263) mA when operating in light sleep mode. Meanwhile, the consumption increased to (265.5) mA when the device measured and transmitted temperature and humidity data to the user. However, the power consumption reached (565.5) mA when the system simultaneously detected motion, collected environmental data, and transmitted the information to the user through the Internet.

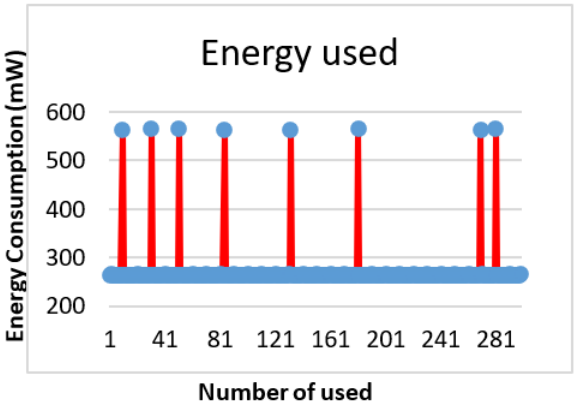


Figure 12: Energy consumption values.

In addition, Table 3 provides a comparative analysis between the proposed motion detection system and previously reported systems in terms of sensing range, energy usage, latency, and environmental influence. The comparison demonstrates that the proposed system offers improved sensing coverage and reduced sensitivity to surrounding environmental conditions compared with conventional PIR-based approaches.

4 CONCLUSIONS

Intelligent home is even now a future dream for everyone. Thus, smart motion detection system is an important device of intelligent home security. It provides crucial benefits such as providing early warnings, and enhance safety for people property and lives, saving money by lower insurance premiums. Therefore, the proposed system sends a notification message on the user mobile and sounds an alarm when it detects an intruder. The heart of the proposed device is ESP32 microcontroller connected with two motion sensors radar RCWL-0516 and HFS-DC06 5.8G for short- and long-range distances respectively. Also, the proposed system includes temperature and humidity sensor and siren device. The aimed of this device is, if there are unusual activities detect by motion sensors, then these motion sensors send signals to the ESP32 and this activate the siren buzzer and light and also send the alert message to the user on his mobile. The user can do a quick response by calling the police or any emergency agent. The user also can control the proposed system by turn ON/OFF the buzzer remotely. Most of the time, the device in sleep mode, except when an event happened, the device is activated. This means that the device is reduced the energy consumption and prolong the battery long time. This project demonstrates how the IoT technology can revolutionize traditional security, providing a scalable and efficient way to protect

properties from intruders. More research is required on the proposed system. For example, we are planning to integrate the device with artificial intelligence technology. The idea is to make the device detect and analysis the human behavior and call the emergence number when an event happened. We will add the camera to recognize human activities using machine learning. Future studies should include prediction and AI analysis by using sophisticated methods to process large datasets and identify hidden patterns. This lead to enhance decision-making, reduce cost and improve the device efficiency.

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