Design of the Amoeba Model Wireless Human Detection Alarm System using Passive Infrared Sensor

Mukesh Kumar Dey[1]

[1](School of Electronics and Communication Engineering, VIT University, Vellore, India)

Abstract : *This paper proposes the design and implementation of an automatic multiple-sensor wireless security system to provide a real-time surveillance and monitoring alarm. The amoeba structure and functional ability of the system makes its implementation possible as a high level security layer, home automation and as an industrial surveillance to secure areas where human reach are restricted. Detection of human is achieved with the use of HCSR501 Passive Infra-red sensors interfaced with the ATMEGA328P Microcontroller. The system includes two smart security layers – first, being the wireless centralized sound alarm designed to raise a general alarming situation to nearby environment that the area under surveillance was breached. The second layer includes the adaptation of the intelligent GSM Technology to allow remote notification and attention of the breached system possible. Additionally, the paper presents the proposed Amoeba pattern along with two common pattern formation for efficient detection of human infra-red radiation. The paper finally explains the code implemented for the human detection alarm using the microcontroller.*
Keywords: *ATMEGA328P, GSM Module, HCSR501, NRF24L01, Serial Communication.*

I. Introduction

A number of alarm systems developed in recent times have tried to analyze and solve the problems with lower hit rates, thereby, increasing the efficiency of the sensing region and ensuring that no false detection occurs. Some alarm systems have been employed to secure access to high-priority areas such as research labs and top-level official areas with the use of the Radio-Frequency Identification Devices [1],[2]. Wireless sensor networks (WSN) have formed the basics of the modern day smart security system for commercial, medical and military domains finding applications in smart-homes, offices and intelligent transportation systems [3]. Other systems that has been developed includes capturing images and sound recording of monitored environment upon detection of a breach in the security [4]. Such methods includes the implementation of sophisticated algorithms to detect, capture and communicate information to the receptor of the system. Some less complex systems includes the detection of fire for home and industrial automation with the use of radio transmission [5]. To achieve the transmission of wireless data efficiently, some systems were incorporated with newer technologies such as Zigbee, Bluetooth and Wi-Fi [6]. The major drawback in all these systems either includes the absence of a practical implementation of the proposed system or the lower hit rates and efficiency involved in sensing the breach in the monitored area. While some low cost devices are limited to only one layer of security, other complex and sophisticated methods makes practical implementation for less budgeted areas like home automation unfavorable.

The current design incorporates the features of a two-layer security alarming system with reduced cost and higher efficiency. Its wireless sensor system allows remote updating of the breached area possible, while the proposed amoeba pattern of upto 6-sensors placement makes the hit-rate and the sensing efficiency comparatively high. The paper also implements the proposed design with cost-effective components, reducing the complexity of the circuit and the need for any sophisticated algorithms. It incorporates the serial communication technology of the Radio Waves to achieve a low-cost wireless transmission of the sensed data. The brain of the system is the ATMEGA328P Microcontroller Integrated Development Board where the sensors and the wireless modules are interfaced. The microcontroller is responsible for controlling and converting the sensed data into serial mode to be transmitted by the Radio Frequency module. The algorithm dynamically provides the condition of the environment to the microcontroller which transmits the data to the two-level receiver sections. Such low-cost Wireless Sensor System can find applications in vast practical areas such as home automation, multi-storeyed buildings and offices. Also, such sensing patterns and systems may be implemented in areas such as museums, where high-level protection and surveillance of historical artifacts is the priority. Thus, the design may solve some of the practical difficulties for implementation of an efficient alarm system. Further, the design can be modified and improved as per the need and requirement of the sensing environment.

Sensors and Wireless Modules

As detection of humans was considered the subject of sensing and low-cost with high accuracy was its priority, the HC-SR501 Passive Infrared Sensor was selected for the current design. It has an operating voltage of (4.5-20)V which makes its interfacing with the microcontroller simpler[7]. Also, the HC-SR501 Passive Infrared Sensor has a 110° Conical Angle of View which is well suited to ensure efficient hit rate in sensing. Additionally, the operating temperature lies between -15° to as high as +70° which allows implementation of the system at various environment possible.

A number of wireless modules are available for efficient data transmission. Some includes adaptation of the Bluetooth, Radio Frequency, GSM, Zigbee and Wi-Fi technologies. As the two major objectives of the current design were cost-effective and remote updation of the breached state, the 2.4 GHz NRF24L01 RF Transceiver was selected for the formation of the wireless mesh network between the transmitters and the centralized receiver where the first layer Piezo Electric Alarm is interfaced and the GSM Module Technology was adapted for the second layer. The low-cost NRF24L01 RF transceiver module can simultaneously accommodate a maximum of six transmitters, thereby, giving an advantage over lower range frequency modules. It operates at an input voltage of (1.9-3.6)V and transmits data in serial mode [8]. The Transceiver has an 'On the Air' data rate of 1 or 2 Mbps. The 900A GSM Shield for ATMEGA328P Microcontroller is a dual band compact and cost-effective module equipped to operate at 900MHz and 1800MHz frequency. It has an operating voltage of (3.1-4.8)V and features Point-to-Point Message Transfer Technology [9]. The Module uses a 12A current during data transmission and thereby it is powered by a 12V DC Adapter.

II. Working Principle

The working of the alarm involves the sensing of the infrared radiation emitted from the human body by the HC-SR501 Passive Infrared Sensor and transmitting the sensed signal to the input pin (Digital Pin 4) of the ATMEGA328P Microcontroller. Using the concept of binary logic, let us assume that whenever any one of the PIR Sensors (P1-P6) detects any infrared radiation, the state of the input to the microcontroller is changed to logical '1' and when no radiation is detected, the state is logical '0'. Additionally, let us consider each transmitter-section as a Node and the centralized receiver-section as the Base. Let us also assume that the state of each node transmitter when no human is detected is 'OFF' and when the detection is positive, the state is changed to 'ON'. Initially, when no human breaches the monitored area, the respective Transmitter is in OFF State. The Base continuously monitors for any of the nodes to achieve an ON condition. As none of the Nodes are ON, no signal is received and the alarms at both the layers remain idle. At any instance of time, when the PIR Sensor captures infrared radiation in the environment, the particular node gets activated to ON State and the Base starts to receive the Signal from that node alone. Upon identification of the node, the base initiates the piezo sound buzzer which raises a high frequency alarm in the neighbouring area of the monitored region as a first-layer security breach. Simultaneously, as a second-layer security measure, the GSM Module is directed to send a text message to the registered number notifying the breach in the security and requesting for immediate attention. The various operations can be summarized in the flow chart as shown in the Fig.1.
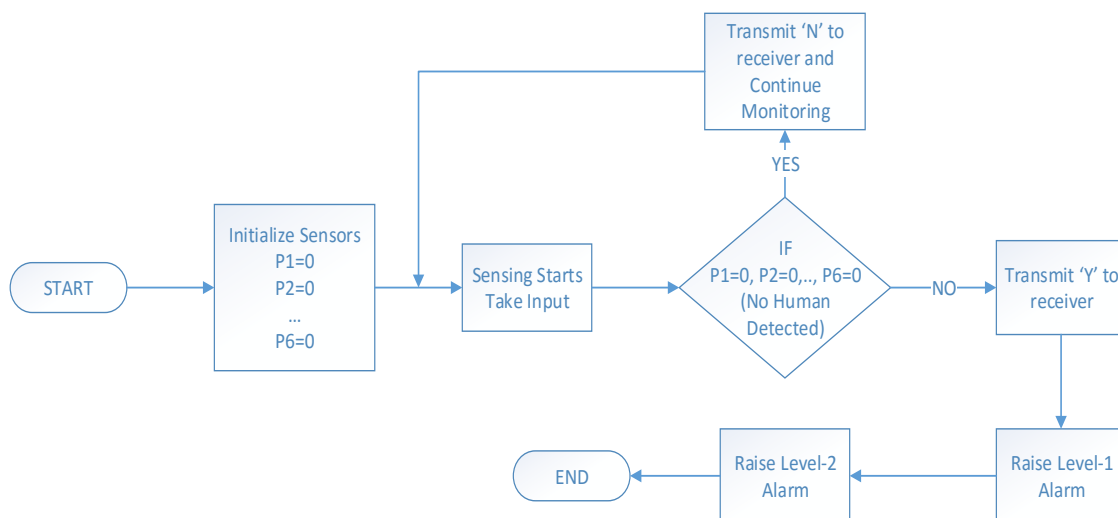
Fig. 1: Flow Chart for Human Detection Alarm

III.   Implementation

Implementation of the human detection alarm system involves interfacing the various sensors and modules to the ATMEGA328P Microcontroller. The various transmitters are independently interfaced to the respective microcontrollers while a centralized receiver-section is adapted, where a single microcontroller operates the control of the level-1 and level-2 security executions. The various connections for an individual transmitter and the receiver section is given in Fig. 2 and Fig. 3 respectively. The implementation further involves coding the transmitter and receiver-sections and uploading the respective instructions to their individual microcontrollers. This is achieved using the common USB 2.0 Male-Male (A-B) peripheral connector. Post uploading of the code, the transmitters are arranged according to the Amoeba pattern suited as per the structure of the area to be monitored and the purpose of the security. The system is then turned on and it starts to secure the area as per the pattern adapted in the placement of the PIR Sensors.
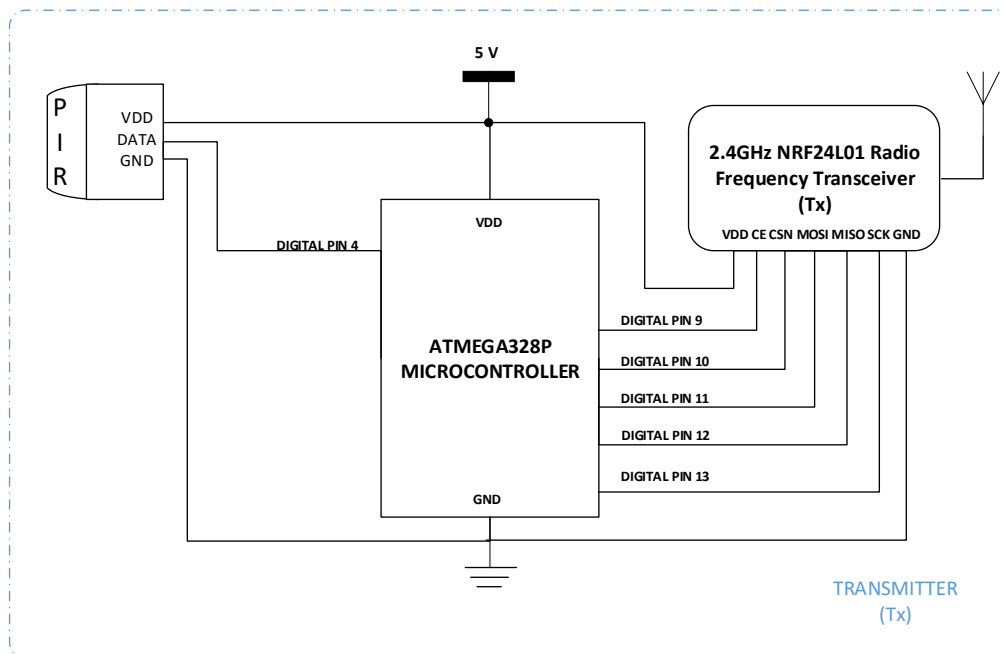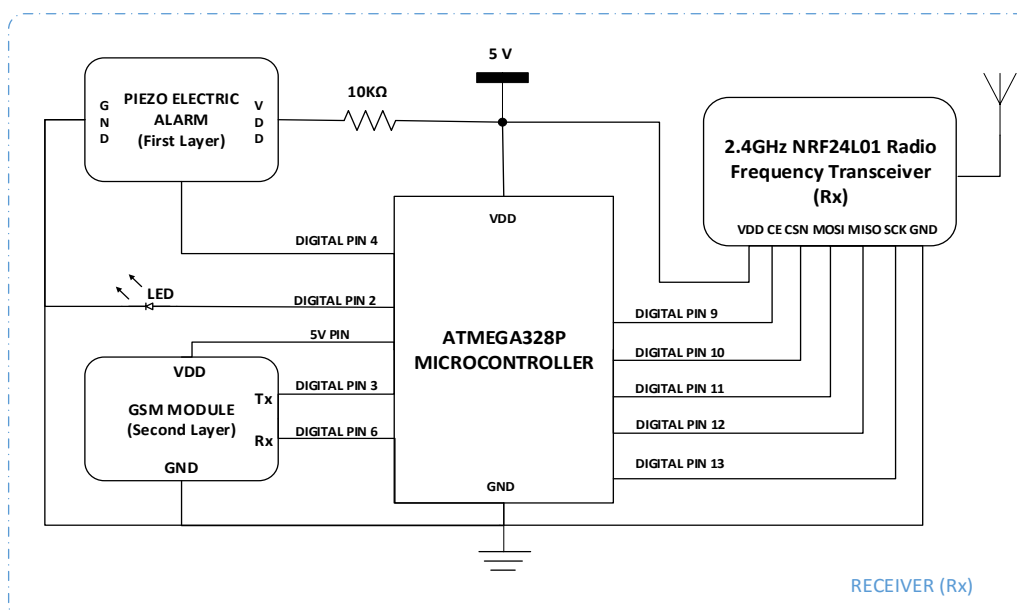
Fig. 2: Connections for individual Transmitter (Node)

Fig. 3: Connections for centralized Receiver (Base)

IV.   Software Implementation

The code for the ATMEGA328P Microcontroller at each individual transmitter-section is given as follows:

```
#include <SPI.h> //Including the Serial Peripheral Interface Library
#include "nRF24L01.h" //Including the NRF24L01 Module Library
#include "RF24.h" //Including the 2.4GHz Radio Frequency Library
#define PIRPin 2 //Set Pin 2 as Input to PIR Sensor
int transmitterId; //Variable to identify individual transmitter
RF24 radio(9, 10); //Setting up Radio at Digital Pin 9 and 10
const uint64_t pipe = 0xE8E8F0F0E1LL; //Setting up Transmitter Pipe Address

void setup(void) {
pinMode(PIRPin, INPUT); //Setting the PIR Pin to Input Mode
transmitterId = 0; //This is the individual Transmitter ID. Change this for different transmitter from 0-6
radio.begin(); //Starting Monitoring
radio.setPayloadSize(2); //Defining the payload size of the transmitter
radio.setDataRate(RF24_250KBPS); //Reducing the bandwidth to improve transmission rate
radio.openWritingPipe(pipe); //Selecting the pipe for transmission
}

void loop(void) {
if (digitalRead(PIRPin) == HIGH) /*If PIR Senses any breach, the transmitter is powered ON to signal the
receiver*/ {
radio.powerUp();
radio.write(&transmitterId, 2);
}
}
```

The code for the ATMEGA328P Microcontroller at the receiver-section is given as follows:

```
#include <SPI.h> //Including the Serial Peripheral Interface Library
#include "nRF24L01.h" //Including the NRF24L01 Module Library
#include "RF24.h" //Including the 2.4GHz Radio Frequency Library
#include <SoftwareSerial.h> //Including the GSM Software Serial Library
#define LED 2 //Set Pin 2 as Output to LED
#define Buzzer 4 //Set Pin 4 as Output to activate Level 1 Piezo Electric Alarm
#define Text 7 //Set Pin 7 as Output to activate Level 2 GSM Module
#define wait 1 //Defining other parameters
#define time 100
SoftwareSerial mySerial(3,6); //Defining the Transmitter and Receiver pins to communicate with GSM module
int senderId;
int freq = 0;
String number ="0996757667"; //This is the 10-Digit Mobile Number to which Second Layer Alert message is
to be sent
RF24 radio(9, 10); //Setting up Radio at Digital Pin 9 and 10
const uint64_t pipe = 0xE8E8F0F0E1LL; //Defining the transmitter address

void setup(void) {
Serial.begin(9600); //Monitoring Starts
radio.begin();
mySerial.begin(9600);
radio.setPayloadSize(2); //Defining the payload size of the transmitter
radio.setDataRate(RF24_250KBPS); //Reducing the bandwidth to improve transmission rate
radio.openReadingPipe(1, pipe); //Selecting one of the 6 pipes for reception
radio.startListening(); //Beginning to listen
pinMode(LED, OUTPUT); //Setting the LED to Output Mode
pinMode(Buzzer, OUTPUT); //Setting the Piezo Electric Alarm to Output Mode
pinMode(Text, OUTPUT); //Setting the GSM Module to Output Mode
}
```

```
void loop(void) {
digitalWrite(LED, LOW); //Setting the LED pin to logical '0'
digitalWrite(Buzzer, LOW); //Setting the Piezo Electric Alarm pin to logical '0'
digitalWrite(Text,LOW); //Setting the Text Key of GSM Module pin to logical '0'
if (radio.available()) /*If any of the transmitters transmits signal*/ {
bool done = false;
while (!done) {
  done = radio.read(&senderId, 2);//Read the Transmitter ID
}
Serial.print("PIR "); //Display the Transmitter ID
Serial.print(senderId);
Serial.println(" On");
Serial.println("Human Detected");//Display that security has been breached
digitalWrite(LED, HIGH); //Activate the LED
digitalWrite(Buzzer, HIGH); //Activate Level 1 Piezo Electric Alarm
digitalWrite(Text, HIGH); //Activate Level 2 GSM Module
for (freq = 0; freq < 4; freq ++){
for (freq = 500; freq < 3000; freq += 10)//Setting the intensity of the alarm
{
tone(Buzzer, freq, time);
delay(wait);
}
for (freq = 3000; freq > 500; freq -= 10)
{
tone(Buzzer, freq, time);
delay(wait);
}
}
if (digitalRead(Text)==HIGH) // If Security is breached, activate Level 2 Security
{
mySerial.println("AT+CMGF=1"); // Setting the Mode of GSM Module as Text Mode
delay(150);
mySerial.println("AT+CMGS=\"+91"+number+"\""); // Specifying the Destination number in international
format
delay(150);
mySerial.print("Warning! Security Breached!"); // Entering the Text message
delay(150);
mySerial.write((byte)0x1A); // End of message
delay(50);
mySerial.println();
}
delay(50); //Waiting till repeating the next cycle
}
}
```

The Amoeba Pattern Formation

The Amoeba pattern can be implemented for any home automation or industrial security system where the distribution of the environment is not even. The placement of the sensors (maximum of six) can be achieved in any pattern and order. A typical Amoeba pattern is highlighted in Fig. 4, where the sensors are randomly placed, leading to the formation of a random secured area. For applications such as surveillance of historical artifacts in museums, a typical fixed pattern can be adapted. This ensures higher efficiency and lower miss-rate which is highly essential to fulfill the purpose. One common formation that can be adapted is the Four Transmitter Square Pattern. This can be achieved by placing the four Transmitters (Nodes) at the two orthogonal axes of the XY-Plane with each Transmitter facing the opposite pair. This placement creates a Square patterned area of surveillance with the artifact at the center. A typical implementation of such placement is shown in Fig. 5. In situations, where the area of surveillance has to be larger and higher security is desired, the Six Transmitter Hexagonal Pattern can be adapted. Here, the six transmitters are positioned at an angle at 60° with respect to its neighbouring transmitters to form a hexagonal area of surveillance. Such systems ensures very high hit-rate and overall protection. The typical formation of the Six Transmitter Hexagonal Pattern is shown in Fig. 6.
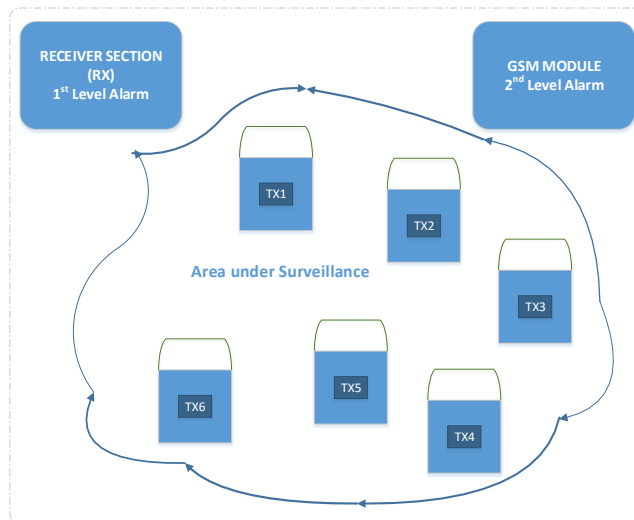
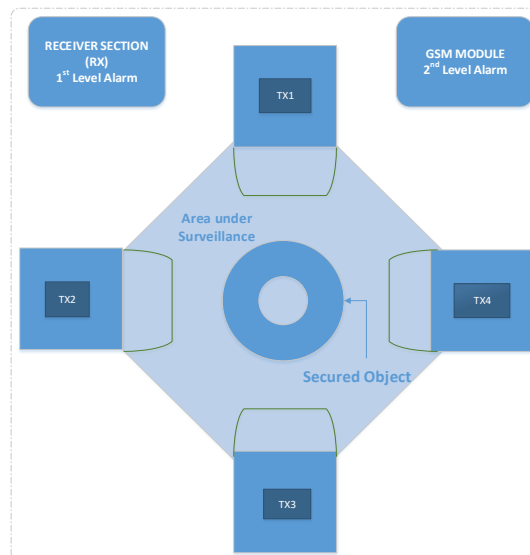**Fig. 4: Six Transmitter Amoeba Pattern**

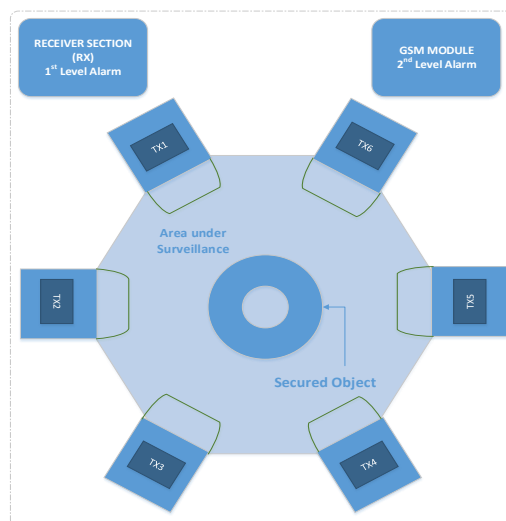**Fig. 5: Four Transmitter Square Pattern**

Fig. 6: Six Transmitter Hexagonal Pattern

V.   Conclusion

The Amoeba Pattern Alarm System finds applications in various environments and is capable of sensing and notifying a breach in the security with much higher efficiency as compared to previous works undertaken that does not involve sophisticated methods. The current model can further be improved with implementation of added layers of security. Further, a reflex action system can be implemented that gets activated whenever a breach in the security is detected, to ensure capture of the intruder as and when required. The implementation of such systems to movable objects such as robots can be used for rescue operations in earthquakes, where a number of transmitters can be monitored by a single receiver to locate trapped humans and signal the appropriate location to the receiver upon detecting a positive signal by the concerned transmitter [10]. Such applications can be undertaken to extend the Amoeba pattern to a more dynamic state of operation with high accuracy and mobility. The current study formulates the basics of such an approach and a dynamic method to achieve low-cost multiple nodes-one base wireless system which is highly researched in today's automation field.

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