Design of 32 Nodes Wireless Sensor Network Through Mesh Networking for Industrial and Residential Security

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Abstract: Industrial and residential security maintenance is one of the major safety concerns for counteracting any unwanted activities. It is not only for protecting the expensive equipment but also for avoiding any hazardous situations. Therefore, the security system has to be robust, dependable and well configured. Retaining these standards, a 32 nodes Wireless sensor security network has been proposed in this paper. The nodes are placed on the glass windows surrounding the floors. Each node consists of a sensor to recognize any cracking sound on the glass by detecting the frequency of it. The Passive Infrared sensor on the nodes can detect any burglar entrance to an unauthorized place. All the nodes are connected to a base station consisting of a launch pad and GSM module via wireless mesh network. Each of the nodes are internally connected via mesh network with the adjacent nodes as a backup protection during any device's malfunction. If the stated node fails to process radio signal to the base station due to channel break then it can send signals via the node beside it. After detecting any breaking noise, the sensor sends a signal by radio frequency to the base station and the GSM module generates an automatic call to the respective number along with a SMS. The flashing light locates the site of the event and the discerning node sends notification to its connecting node about the occurred incidence. If a burglar tries to disrupt any node, the PIR sensor detects from a 10 meter distance and will generate the alarm before he can proceed. The system requires very low power and hence ensures long battery life.

Keywords: Wireless Sensor Network, Mesh Networking, Glass breakage sensor, Anti-theft system, GSM alert.

1 INTRODUCTION

Wireless sensor networks are very high efficient technology due to its wide range of applications, while represent a good example of multidisciplinary work that closely match the industry field. For decades, security is one of the major issues in industry and different types of developed systems are being implemented. But still we are unable to find a stable solution of this problem. One most common solution can be using CCTV camera 24 hours at every possible places in the industry. Different security systems are implemented based on CCTV system like "Experimental Analysis of Face Recognition on Still and CCTV Images" [1]. "Automatic CCTV surveillance-towards the virtual guard" [2] etc. But these systems are costly and complex due to face recognition system. Face recognition means complex algorithms and sometimes the system may be unable to detect the burglar's identification correctly and keeps a computer chip busy for longer time. For CCTV security a person needs

to monitor the camera footage or live video all the time. There are also other security systems like “Prototype implementation of SMS based home automation system” [3], “The Design of Intelligent Household Control System Based on Internet and GSM” [4]. These system works as an individual system and each device needs a GSM module to make call or generate alert. This makes the system very much costly as each devices need individual GSM modules. On another research work “Theft prevention using wireless security system (WSS)” [5] is proposed but this system needs a server to store RFID data and it’s not a cost effective solution. Other laser type security system “A design of alarm system for substation perimeter based on laser fence and wireless communication” [6], in this system the device power can be cut off or the burglar can pass off the laser beam that will not let the security alarm to function. In this work a new system is proposed and 32 (more/less) nodes are connected individually with only a single base station using a single GSM module. All the nodes are connected with each other via mesh networking. The glass cracking sensor in the nodes can detect any crack occurs in the home or industry windows. PIR sensors can detect any human interference with in the restricted area. If any cracking occurs the glass cracking sensor detects the crack via cracking sound frequency and sends a signal through RF to the base station node. On the other hand if PIR sensor detects a human within its 10 meter range it will also send signals through RF to the base station. Then GSM module at the base station will generate a call & SMS to the given number .The system will notify by generating an alarm through the wireless alarm. It also indicates the incident occurrence area by flashing particular lights to highlight the place.

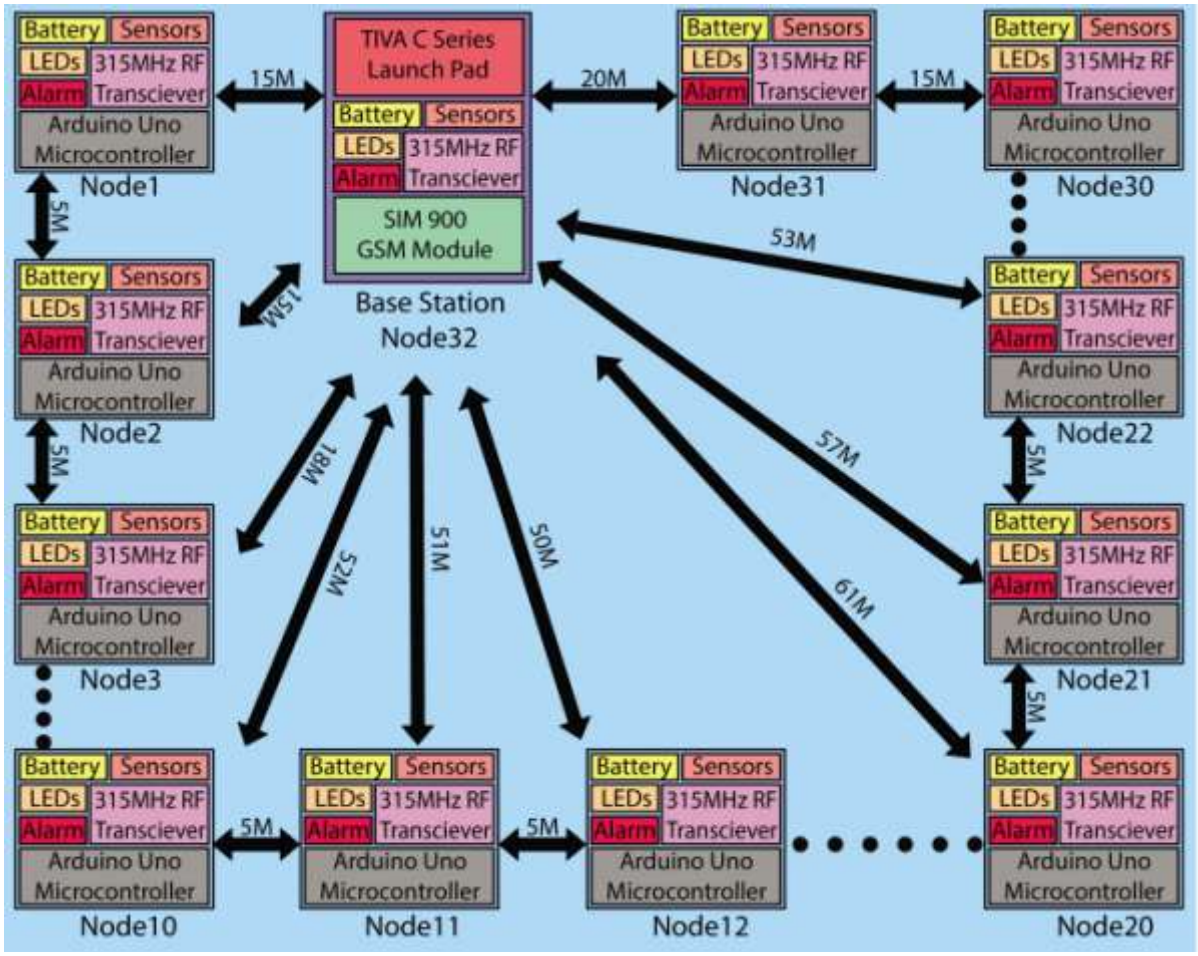

Figure 1: Basic Project Outline

2. BASIC PROJECT OUTLINE:

In the above figure the overall project diagram is shown. Here thirty two nodes have been used to communicate between each other and the base station module. Each node is placed at the window of an industry having 5m of space in between. And the base module is placed at the entrance. Each node is used to detect any glass breakage or the presence of any burglar. Once a node detects any of these two incidents it communicates with three nodes. At first it sends alert to the base node, then it transmits to its right closest node and then to its left closest node. This kind of mesh network is designed to develop alert confirmation system. Each node is placed on a window and between each window there is 5m of space. So, each node is 5m away from its closest node. The distance of each node from the base node is also critical. From Pythagorean Theorem [7] the distance between each node and base module is shown in the figure. The closest node from base is about 15m away and the furthest node is around 61m away. These RF devices have a range of 80m line of sight. If for some reason the specific node is unable to alert base module, other two closest nodes will certainly alert the base module. Each node consists of several sensors, led indicator, alarm, RF transceiver & portable battery. Base module acts as a node itself also. So it contains all the components of a node and additionally it also contains GSM module to alert user.

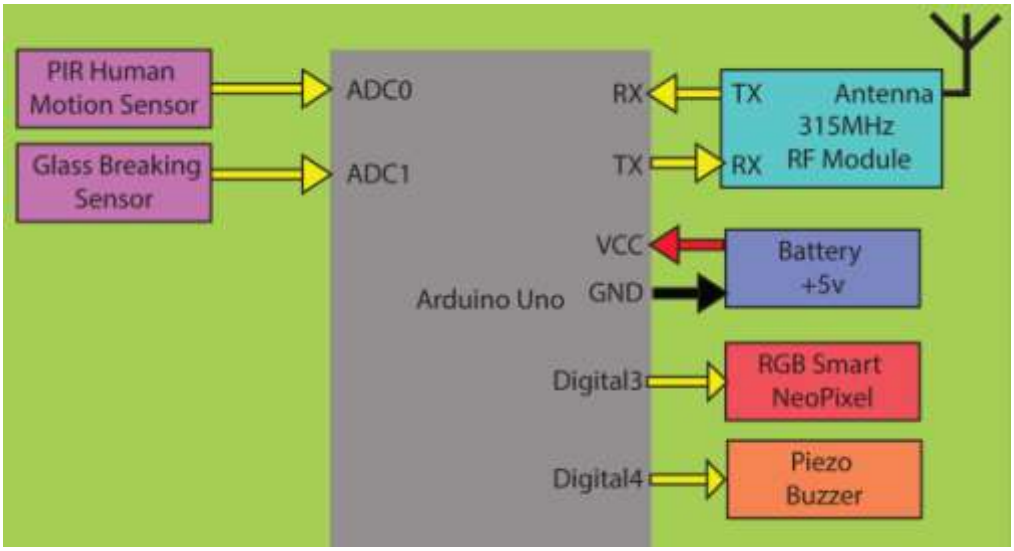

Figure 2: Block Diagram of node module

Figure 2 shows the details of an individual node. At input side of the node it contains two sensors. These are human motion detection sensor and glass breakage detection sensor. In processing unit Arduino Uno is used. At output side leds, buzzer is connected. A rechargeable +5v battery is used to power the whole node. In order to transmit data to base node and other two closest node RF transmitter is used. RF receiver receives instructions from base module or alert from other nodes. The entrance of each window need to be protected . A node is placed in each of the glass. If the sensors detects the presence of human or and breakage in glass, it starts buzzing through buzzer and transmits burglar alert to its nearest two nodes. After receiving alert from adjacent two nodes also starts to light up their LeDs , start buzzing. This alert is also received by the base module. This generates a larger amplitude alarm and calls to the owner, sends SMS of burglar alert. If burglar somehow able to avoid human motion sensor, another sensor will work on, the glass breakage sensor. In order to enter inside the industry the burglar has to break window. If he breaks any windows the sensor generates an indication of window breakage and micro-controller turn on all the alerts.

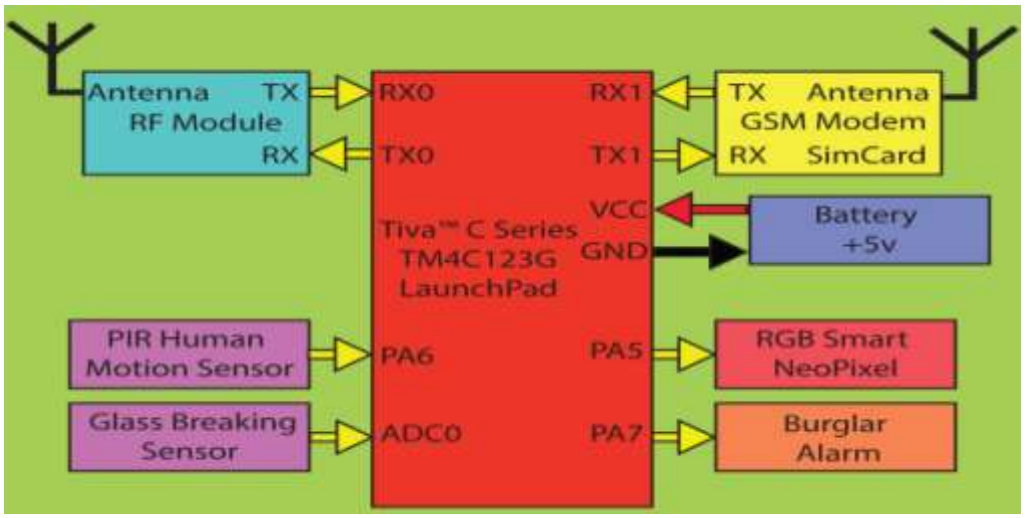

Figure 3: Block Diagram of base module node

Figure 3 shows the Base module which is more complex than an individual module. It acts as a node and a base module simultaneously. It consists of all the components of a individual node and additionally it also has GSM module. Here as the processing unit Tiva C series TM4c123G Launch Pad is used. This launch Pad is built by a 32bit ARM Cortex M4 processor. As RF transceiver & GSM module both communicates through UART, a micro-controller is chosen which has multiple UART facility. Also as the module has to act as a node and as a base module higher speed is required. This micro-controller is the fastest micro-controller present in the market. Base module is also portable.

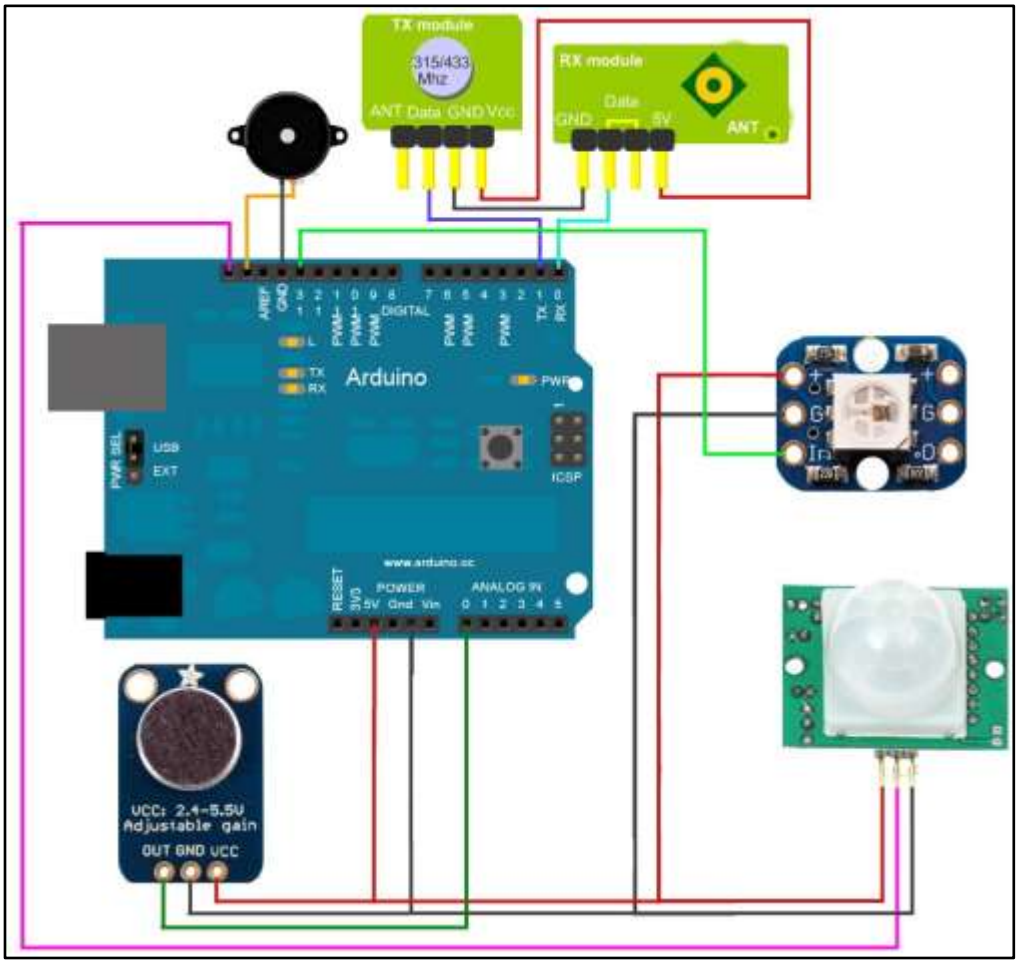

Figure 4: Circuit diagram of individual node

3 Circuit Analyses:

I. Node Module: Heart of the node module is Arduino Uno, a 8bit 16Mhz speed micro-controller. Arduino Uno is powered by a +5v battery. From Arduino Uno +5v & +3.3v is used as the power for other devices. Here Electret Microphone Amplifier - MAX4466 is used as glass breakage sensor. This sensor has three pins VCC, GND & OUT. VCC of this sensor works in 2.4-5VDC. To ensure the best performance of Arduino 3.3 V is used. Ground pin of the sensor is connected with the ground pin of Arduino. The audio waveform will come out of the OUT pin. To measure the frequency and amplitude of this audio waveform it is needed to be sampled. That's why the output pin of the sensor is connected with the ADC (Analog to Digital Conversion) pin. PIR (Passive Infra-Red) sensor is connected with the common +5v Vcc & Ground pin. Output of PIR sensor can be connected with any digital I/O pin of Arduino uno. Output of PIR sensor is connected with the digital 8 pin. In output portion a RGB LED is used. These LEDs are called RGB Smart NeoPixel. It has three pins Ground, VCC and Data in. To get the brightest light RGB led is connected with +5v DC. Data in pin is used to transmit data for desired color. This pin should be connected with PWM pins but in Arduino uno library any digital pin can be used as PWM pin to handle this RGB led. Here at digital 3 pin Data In pin is connected. The buzzer can be controlled through any digital pin. Another leg of buzzer is connected to ground. Two RF module with same frequency is connected with Arduino. Here both the module uses +5v power input. The TX module transmits and receives data from Arduino. Tx pin of RF Transmitter is connected with Tx pin of Arduino and Rx pin of receiver module is connected to Rx pin of Arduino. When sensor detects any human or glass breakage it transmits signal to micro-controller and the micro-controller turn on RED LeD and the buzzer. Through Tx module Arduino transmits alert to adjacent two node and base module. Rx modules of other nodes receive this alert and Rx pin of Arduino receive the alert.

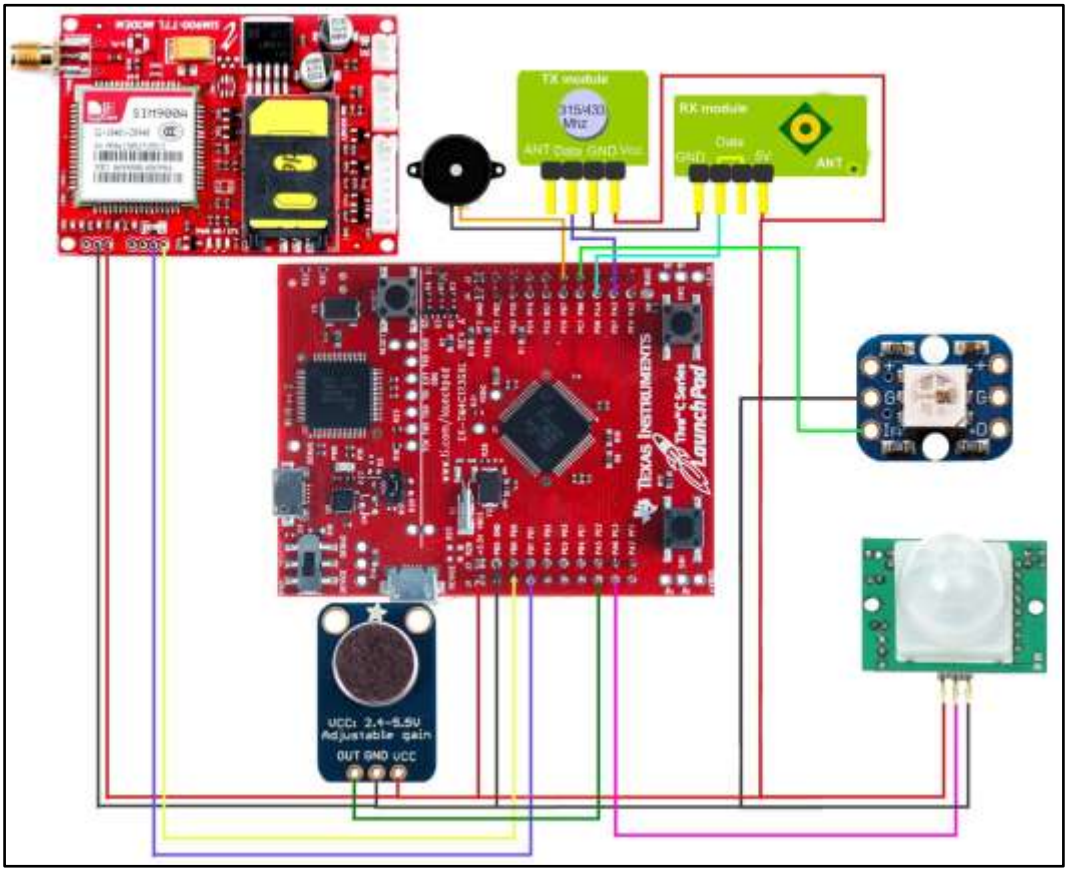

Figure 5: Circuit diagram of base station module

II. Base Station Module: Heart of base module is Tiva™ C Series TM4C123G Launch Pad. It's an ARM Cortex™-M4F-based microcontroller. Board power supply of this device is from 4.75 VDC to 5.25 VDC. In this project a +5v battery is used to power up the board. Glass breakage sensor is connected with ADC0 pin of micro-controller. The output of PIR sensor is connected to digital PA6 pin. RGB led is controlled through digital pin PD6. Positive pin of piezo buzzer is connected with the digital pin PB7. Two UART of this module is used to connect RF & GSM module. GSM module is powered by VBUS of the board. VBUS is +5v as the input voltage of the board is +5v. GSM module is connected to UART1 of micro-controller. Rx and Tx pin of GSM module is connected with Tx (PB1 pin) & Rx (PB0 pin) of TM4C123G launch pad respectively. RF transceiver is connected through UART2. Rx pin (PD6) of micro-controller is connected with Rx pin of receiving module. And Tx pin (PD7) of micro-controller transmits data through Tx pin of transmission module.

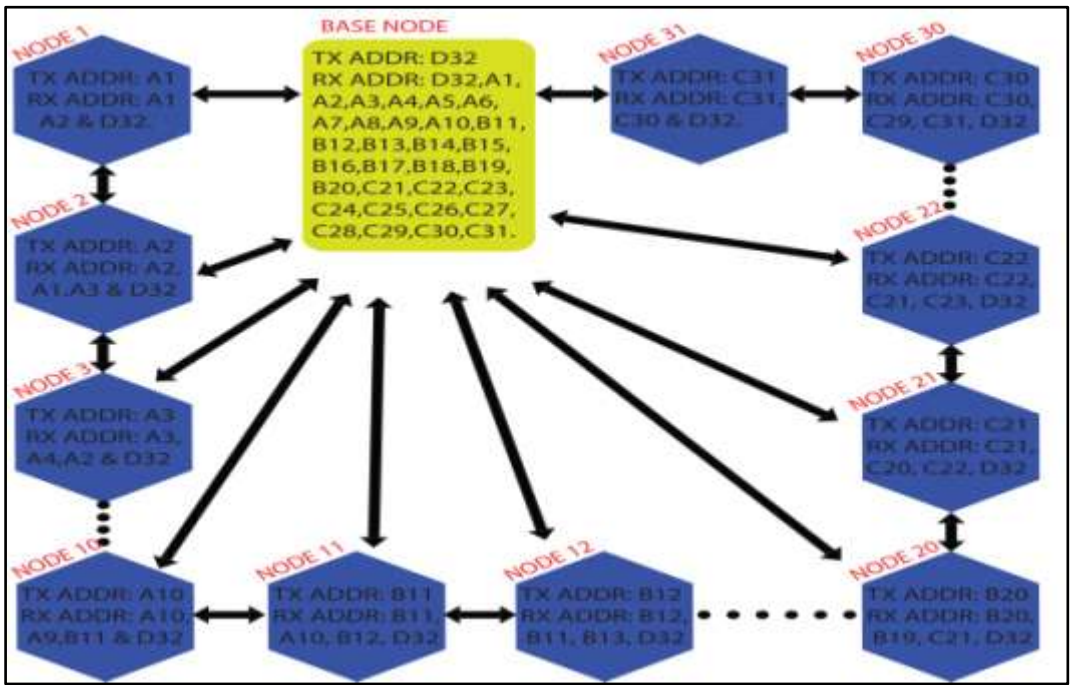

Figure 6: Mesh Network Topology between 32 Nodes

4. MAIN TECHNOLOGY USED

All RF transmitters transmit data at 315MHz and all receiver modules are capable of capturing data. So the networking is done in software. Here TX ADDR is the transmission address of the node and RX ADDR is the address of nodes which it listens to only. Bellow the packaging format of Transmission module is shown

AA<Node Address><~Node Address><Human Detected><~Human Detected><Glass Breakage><~Glass Breakage>Z

Here AA means the starting of data transmission and Z means the end of data transmission. Between the start and end syntax indication the data is provided. First value indicates the Node address, which is written in hex format. For example if node 3 transmits, node address will be 0x03. If any human is detected 0x01 is transmitted and if not detected it transmit 0x00. Same is for Glass Breakage, 0x01 indicate the glass breakage and 0x00 means not detected. A data needs to be transmitted after a data inverse. So the value of Node Address in binary is 0b00000011 and ~Node Address is 0b11111100. Same for other variables. As Before transmitting data micro-controller has to initialize UART (Universal Asynchronous Receiver and Transmitter) at a fixed baud rate. Usually UART communicate at 9600kbps baud rate. Due to high noise, baud rate 2400kbps is used because lower baud rate gives good accuracy of data. Tx pin of microcontroller transmits this packet to RF module and RF module transmits these packets wirelessly to receiver module. At the receiver end micro-controller initialize its UART at 2400kbps baud rate and waits for data to come. When micro-controller receives the packet it checks all the value whether inverse of inverted values are equal. If they are equal micro-controller continues to read the next values. If all the data is received properly it goes further and checks for the node address from which it is permissible to receive only. If all the data matches it turn on its alarm after receiving alert from its adjacent node. When Node 03 transmits an alert, node02, node04 and base node receive the alert. Same goes for others when node 20 transmits only node21, 22 and base node accept alert. Sample Tx and Rx code is given below for node 20

```
RxAddr = 0xB20;

UWriteData('A'); UWriteData('A');

UWriteData(RxAddr); UWriteData(~RxAddr);

UWriteData(human); UWriteData(~human);

UWriteData(glass); UWriteData(~glass); UWriteData('Z');
```

Receiving code for node 20

```
TxAddr=UReadData();

If(TxAddr == 0xC21 || TxAddr == 0xB19)

{ Sound_Play(880, 1000);//set alarm}
```

5. HARDWARE IMPLEMENTATION

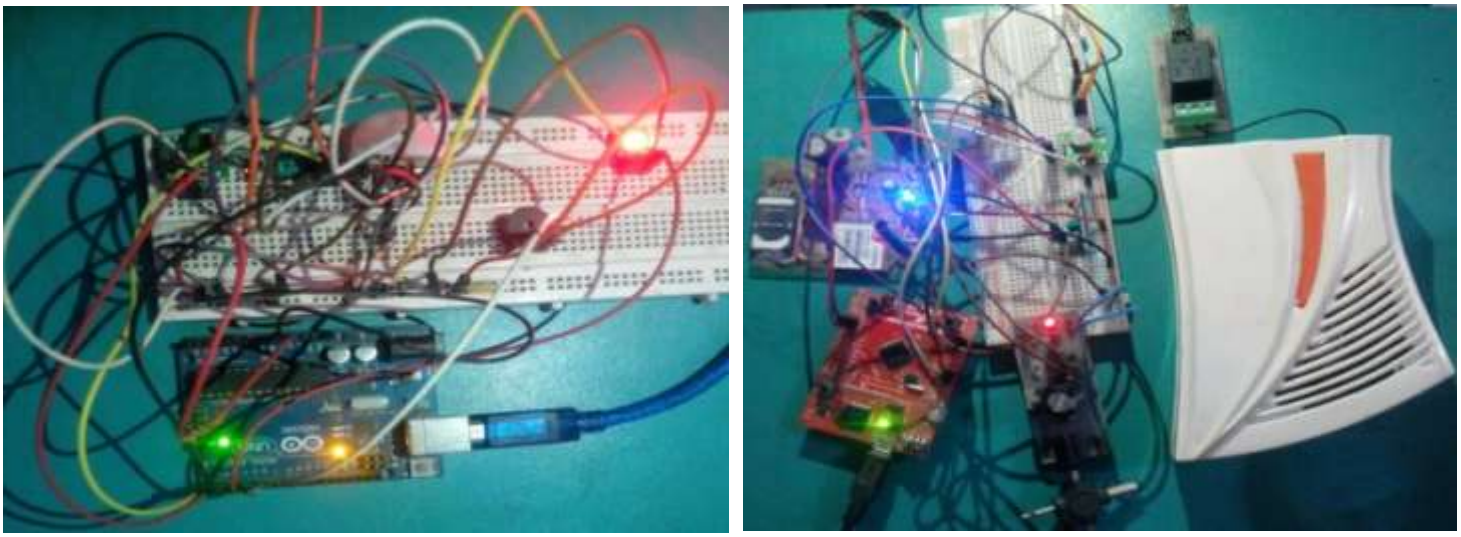

Figure 7: Hardware Implementation of Node and Base Module

A simple glass breakage detector works on the spectral analysis of a typical glass breakage signal. The input signal spectrum, limited to a frequency of 20 kHz, is processed for a valid glass breakage. The detector analyzes acoustic signals produced during a glass breakage. These acoustic signals are analyzed after being captured by an onboard microphone. The input signal is captured by a Panasonic WM-61A microphone that has a frequency response between 20 Hz and 20 kHz and can operate at voltages up to 10 V. The microphone has a high signal-to-noise ratio that is approximately 60 dB. It is turned on in every 2 ms When the input signal needs to be captured, the signal analysis is done in every sample and its completed before the arrival of the next sample. Then the signal analysis is done on 60 ms of the incoming data. With Over 2000 samples the number of peaks and zero crossing of the samples are counted. These values are now used to detect a glass breakage. According to the category of the industry glass if the number of peaks is between 200 to 300 and if the number of zero crossing ranges from 120 to 280, that means glass is broken.

As the PIR sensor is connected to a digital pin, the pin needs to be pulled down to detect the high voltage of the sensor. Whenever any human passes in front of the sensor it generates a high voltage. The digital pin of microcontroller is internally pulled down.

If any of these two incident occurs the gsm module generates call & SMS to the user. To generate call and SMS GSM code is given below

```
UART1_WRITE_TEXT("AT+CMGS=\"+8801715021687\"\R");
delay_ms(100);
  uart1_write_text("Burglar Alert: Glass Breakage Detected on Window No.7");
  uart1_write(26);
```

6. SYSTEM OUTPUTS & RESULTS

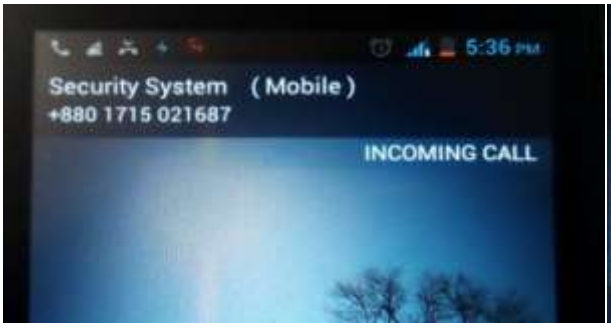

Figure 8: Incoming call from GSM module

Figure 9: Incoming SMS from GSM module

When the PIR sensor detects human at a unauthorized place or the glass sensor detects any breakage then the corresponding node send detection signal to the base station and via GSM module call and SMS is generated to the respective concern's phone number.

7. CONCLUSION:

In this system a large number of nodes are used to cover a large floor. This system should be turned on when there is no human in the secured place. Otherwise the PIR sensor will detect and generate a false alarm and a false call. It's not capable to differentiate between burglar and any authorized person. It can detect human entrance but can't take steps to grab the burglar by locking the door. It not able to give protection to the industry/home machine equipment's from being stolen. In future further improvements can be made taking the above matters into account

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References

Chen,S. Berglund, E. ; Bigdeli, A. ; Sanderson, C. ; Lovell, B.C. "Experimental Analysis of Face Recognition on Still and CCTV Images" IEEE Fifth International Conference on Advanced Video and Signal Based Surveillance, 2008. AVSS '08.

Thiel, G "Automatic CCTV surveillance-towards the VIRTUAL GUARD" Aerospace and Electronic Systems Magazine, IEEE Volume 15 Issue 7

Elkamchouchi, H. ElShafee, A. "Prototype implementation of SMS based home automation system" IEEE International Conference on Electronics Design, Systems and Applications (ICEDSA), 2012

Li Wei Yu Min ; Cheng LiangLiang ; Chu Ping "The Design of Intelligent Household Control System Based on Internet and GSM" Second International Conference on Networking and Distributed Computing (ICNDC), 2011 .

Chee Kyun Ng Kong Seng Wee ; Noordin, N.K. ; Iqbal Saripan, M. ; Syamsul, R. ; Abdullah, A.R "Theft prevention using wireless security system (WSS)" RF and Microwave Conference, 2008. RFM 2008. IEEE International

Chunjuan Wei Junjie Yang ; Wu Zhu ; Jian Lv "A design of alarm system for substation perimeter based on laser fence and wireless communication" Computer Application and System Modeling (ICCASM), 2010 International Conference on (Volume 3)

http://www.mathopenref.com/pythagorastheorem.html