WiFi Enabled Home Security Surveillance System using Raspberry Pi and IoT Module

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***Abstract*—This paper details the design and development of IoT based security surveillance system in buildings using Raspberry Pi Single Board Computer(SBC) with WiFi network connectivity. Adding wireless fidelity to embedded systems will open up various feasibilities such as worldwide monitoring and control, reliable data storage etc. This system comprises of wireless sensor nodes and a controller section for surveillance. Remote user alerts, live video streaming and portability are the prime features of the system. WiFi enabled IoT(Internet of Things) module processes the sensor based events and sends the sensor status to controller section. Upon receiving the event notification, the controller enables the camera for capturing the event, alerts the user via email, phone call and SMS and places the live video of event on webpage. The IoT module eliminates the need of a microcontroller and wireless transceiver module in sensor node, thus it makes the node compact, cost effective and easy to use. The biggest advantage of the system is that the user can seek surveillance from anywhere in the world and can respond according to the situations.**

***Index Terms*—Surveillance, Sensor node, Wireless sensor networks, Single Board Computer, Internet of Things**

I. INTRODUCTION

In the present situation, ensuring safety and security has become an inevitable essentiality. Since it is well known that influence of modern technology has reached its peak, demand for security systems are going up progressively. Modern home needs intelligent systems with minimum human effort. With the advent of digital and wireless technologies, automated security systems becomes more intelligent. Surveillance camera helps the user to get a remote view of his home and the sensor networks add extra security features depending on the type of sensors. Adding WiFi to security systems enables faster data transmission, and it will help the user to monitor and control the systems globally.

A. Survey of Existing Systems

Among the existing surveillance techniques, CCTV is the most commonly used one. But it has its own limitations. It is a passive monitoring device and it needs continuous human intervention for monitoring. The investigation is a little bit hectic thing since all the previously recorded videos need to be watched manually. Moreover files can be corrupted very easily and this technique is costly too. These limitations lead to the development of active surveillance system. Several researchers have come up with the idea of active surveillance systems in various papers. Most of the papers utilize the advantage of Wireless Sensor Networks (WSN) for surveillance. Since the sensor nodes being wireless, they can be placed anywhere inside the building, thus it achieves portability in deployment.

Zhao *et.al.* proposed a WSN based surveillance system monitored by Programmable System on Chip (PSoC) devices [1]. Here Zigbee module is used for wireless transmission. The system mainly concentrates on sensor based alerts and it lacks improved techniques like camera, web server for uploading files etc.

Rakesh *et.al.* proposed an improved real time home security system using BeagleBoard and Zigbee [2]. Remote alert on fire and intruder detection are the main features of the system. It uses improved techniques such as camera, GSM, FTP server etc. But it is not utilizing the advantage of live streaming and alerting techniques such as phone calls, SMS and email etc.

Ansari *et.al.* proposed an Internet of Things approach for motion detection using Raspberry Pi [3]. It utilizes FTP server for camera feeds and it alerts user through email. The system does not have SMS and phone call alerts and other sensor alerts such as detection of fire, gas etc.

Muheden *et.al.* in their paper explains a WSN based fire alarm system using Arduino [4]. The system is purely based on sensor alerts and it lacks other features like camera, web server etc.

Kumar *et.al.* in their paper describes the surveillance technique using IP camera and arduino board[5]. In this paper, user can view remote desktop using team viewer application whenever he need to monitor his home from outside. This system is not sending any notification to user whenever any event occurs in his home. User has to monitor his home continuously and also it lacks sensor based alerts.

Most of the previous papers on security systems are utilizing zigbee based WSN. But it has limited range and bandwidth. Some of the papers describes sensor alerts and it lacks the video surveillance, web servers, live streaming etc. Some are the purely based on sensors. Such systems are implemented

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using microcontroller or computer. Since microcontroller cannot perform multiple functions at a time, the same can be achieved by making use of a computer. But computer is very expensive and consumes more power.

In this paper, we introduce a newly revised security system using Raspberry Pi and NodeMCU (IoT/WiFi module) which integrates sensor alerts with video surveillance techniques. Raspberry Pi is a low cost, low power, single board computer which can handle multiple functions like a normal computer. Intrusion and fire detection are the prime features of this system. This system is purely based on WiFi connectivity. Here, we use WiFi module for wireless transmission instead of Zigbee. Having WiFi connectivity is an added advantage for any system. Data can be fetched from anywhere and it can be moved to cloud for storage and monitoring. Also it has long range and high bandwidth, that is why it is perfect for streaming video, sending email etc. Moreover, the IoT module makes the system cost effective, compact, globally controllable and accessible. The objective of our paper is to design and implement a low cost, reliable, energy efficient, long range, globally accessible, storage effective surveillance system using Raspberry Pi SBC, GSM Modem and NodeMCU (IoT Module).

The paper is organised as follows: Section II describes the architecture of the system. In Section III, design and working of the entire system is discussed and in section IV, the implementation results are shared. In section V, the advantages of system is given. The conclusion is drawn in section VI

II. IoT BASED SYSTEM ARCHITECTURE

Fig. 1 shows the detailed architecture of IoT based surveillance system. The entire system is divided into two parts:

- WiFi enabled sensor nodes
- Surveillance controller system (Master node).

It is mandatory that both sensor and master node should be on same network. Being the sensor node as wireless, it can be easily installed anywhere inside home. Sensor nodes follows modular design so that any number of nodes can be added or removed.

A. WiFi enabled sensor nodes

Here, sensor nodes are organised as modules. Each module consists of a sensor node followed by a NodeMCU (ESP8266). NodeMCU is a low cost open source WiFi module used for IoT applications. The sensor is connected to the IoT module which will process the sensor output and updates the sensor status to master node via WiFi.

There are two types of sensor nodes in this system. Passive Infrared (PIR) Motion sensor node and Fire detection sensor node. PIR node will detect the presence of the intruder and it can be installed in entry restricted areas or other critical areas. Fire node will detect the presence of fire, triggers buzzer and activates the fire safety device i.e.; a fire ball.

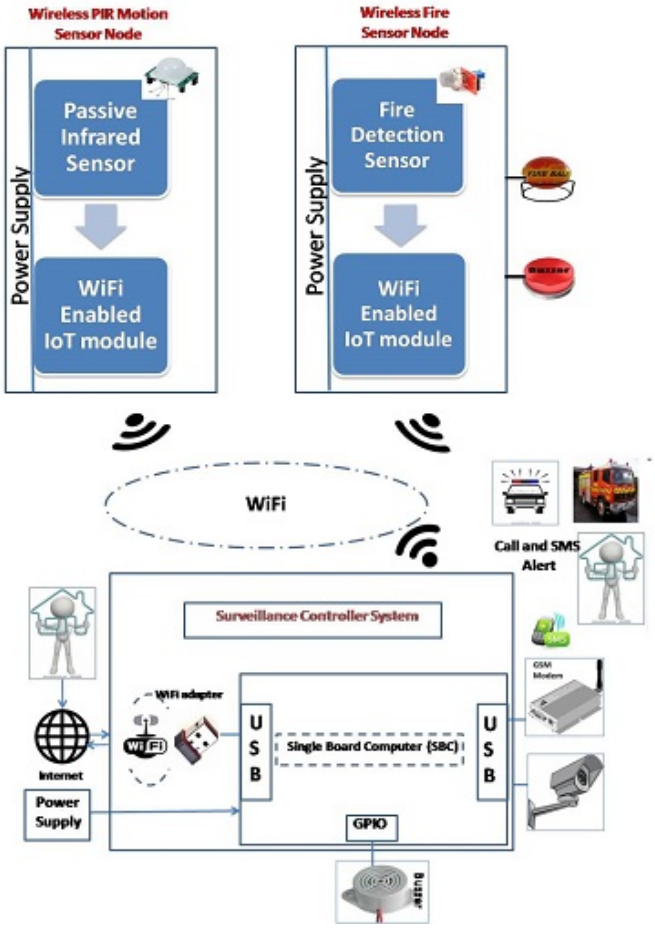

Fig. 1. IoT based System Architecture

B. Surveillance Controller System (Master Node)

It is built on Raspberry Pi (RPi) SBC with a Linux based operating system Raspibian installed into it. RPi is a low cost, low power, credit card sized computer. Master node consists of webcam for video surveillance, GSM for remote notification, and buzzer for emergency alert. This node handles various functions such as managing the sensor feeds, camera feeds, SMS and call alerts via GSM, email alerts, video streaming etc. NodeMCU is programmed to work as a WiFi server. Here the system is connected to WiFi through a USB WiFi adapter. The master node acts according to the sensor updates from the sensor nodes. Once it receives the sensor status, webcam will be activated and events will be recorded. User can watch the live video of event from anywhere using the IP address of RPi. GSM Modem will send notification to selected users such as owner, fire force, police etc. The system also sends email notification to user.

III. SYSTEM DESIGN AND WORKING

A. Hardware Design

The system is designed as an embedded system which has two parts: WiFi enabled sensor nodes and Surveillance

Controller System. The hardware design of each part is as follows:

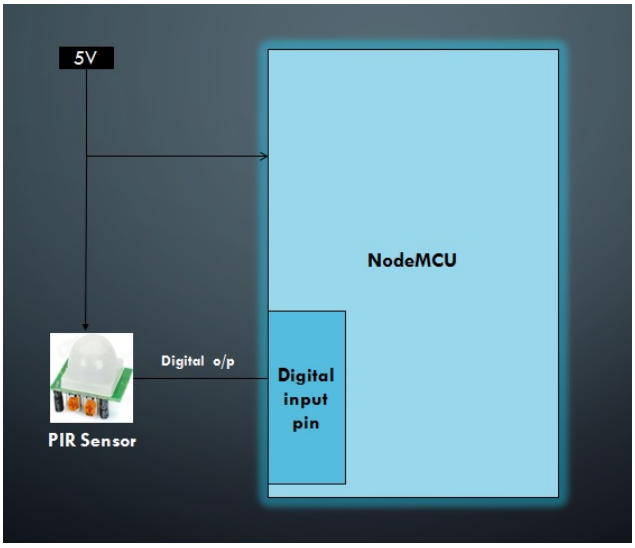

Fig. 2. PIR Sensor Node Schematic

1) Hardware design of PIR sensor node: Fig. 2 shows the schematic block diagram of the PIR sensor node. It consists of NodeMCU(ESP8226) module for interfacing the sensor. NodeMCU is a low cost, smart, open source WiFi module for carrying out IoT applications. It has 10 GPIO pins, micro usb for power and flash and a PCB antenna. It is very easy to use since the size is very small.

PIR sensor is a three pin device which works from 5V. It detects motion by measuring the changes in infrared radiation level of human beings. The presence of intruder is indicated by a logic high value at the output pin. . It receives the sensor output and displays the sensor status in a webpage. The webpage can be viewed in browser using the IP Address of NodeMCU. Master node can get the sensor values from webpage since both the sensor and master node are connected to same WiFi server.

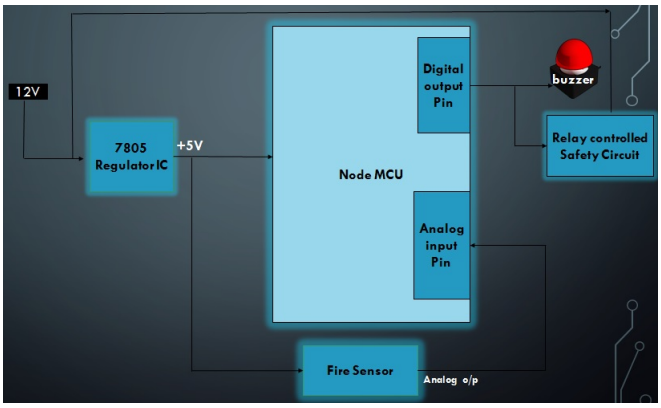

Fig. 3. Fire Sensor Node Schematic

2) Hardware design of fire detection sensor node: Fig. 3 shows the schematic block diagram of Fire sensor node. It consists of Temperature sensor LM35 for detecting fire (Fire is indicated by an increase in temperature). The output of LM35 is analog in nature and it is connected to analog pin of NodeMCU. When the presence of fire is detected, buzzer buzzes and fire safety device is activated. The operation of fire safety device is controlled by a relay. We use 12V power supply since the selected safety device need 12V to work. Since NodeMCU will not support more than 5V, 12V supply is regulated to 5V and fed to NodeMCU. In order to control the operation of the safety device, 12V relay is used. Relay is driven by a transistor which is connected to the digital pin of MCU. The presence of fire will turn on the transistor relay driver circuit and safety device is activated.

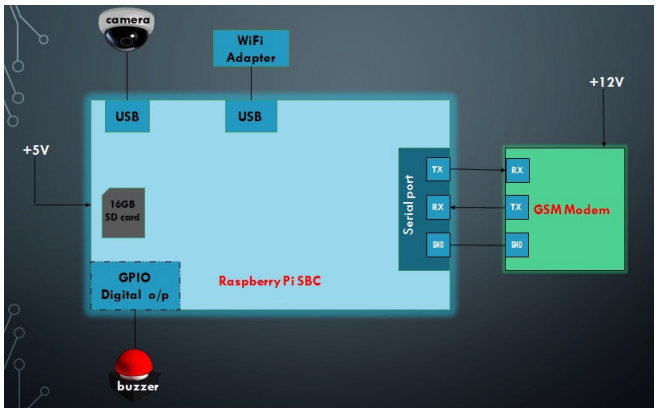

Fig. 4. Master Node Schematic

Fig. 4 shows the hardware schematic of Master node. It consists of Raspberry Pi, USB WebCam, GSM modem and a buzzer. RPi is connected to WiFi using WiFi adapter. USB camera is connected to RPi via USB port and buzzer is connected via GPIO pins. GSM modem is interfaced with RPi using serial ports RX and TX. RPi is powered using a USB 5V supply and GSM modem is powered using a 12V adapter.

USB Camera will be in inactive state normally and it will move to active state when intruder's presence is detected. It will capture the video, records the event and it is stored in RPi for future reference. User can watch the stored video in case he missed live stream. The event is notified to user via GSM modem.

B. Software Design

Fig. 5 shows the detailed software design of the system. It is divided into two sections. Wireless sensor node software design and Master node software design.

1) Wireless sensor node software design: Sensor node is made as wireless by programming the NodeMCU board to work in WiFi. It is programmed with Arduino IDE using C language. We need to follow certain steps like installation of required libraries and packages, selection of programming board etc. in IDE to program NodeMCU. After flashing our code into NodeMCU, the board will be connected to WiFi and it will be turned into a WiFi web server. The IP address of the board can be seen in the serial monitor window. Web server

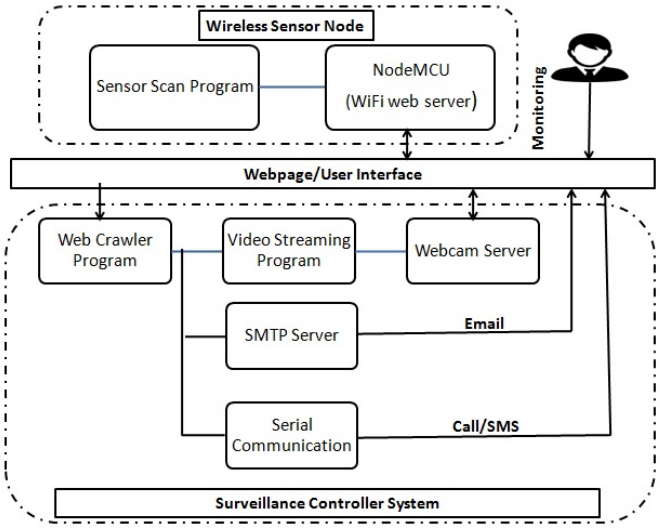

Fig. 5. Software Design of Proposed System

can be accessed by typing the NodeMCU's IP address in web browser. Sensors connected to the NodeMCU will sense the event and the MCU will send the sensor status to webpage. Occurrence of an event is indicated in webpage by a logic high value.

2) Master node software design: A Linux based Operating System (OS) called Raspibian OS is installed into SD card. RPi's desktop is accessed from laptop using ssh remote login. Then all the required libraries and softwares such as Open Source Computer Vision (OpenCV), Python, streaming software (Motion), web server etc. were installed into it. We have used OpenCV-python for writing application programs. Live streaming is done by executing the motion software and webcam server will display the corresponding live video on a webpage. In order to send email using python, we use Simple Mail Transfer Protocol (SMTP) object. SMTP object will access the SMTP server and the email is routed to the recipient. RPi communicates with GSM modem via serial Port. RPi sends suitable AT commands to GSM modem and it will respond back by sending SMS and making calls to the respective mobile numbers.

Whenever there is an event in sensor node, master node will execute various functions. Sensor node will update its status regularly to a webpage. Master node will crawl the sensor node's webpage using a web crawler. If the crawled data has a logic high sensor value, then the master node will trigger a python script which executes a sequence of functions such as live streaming, email alert, SMS and call alert etc. Live streaming is achieved by setting various parameters such as Webcam streaming Port, framerate etc. in the motion configuration file of RPi. Video can be watched in local network by typing RPi's IP Address followed by the corresponding Port.

In order to watch live video from anywhere, we use Port Forwarding Technique. It is a technique where the internal IP address and Port of a device is mapped to the external IP address and Port. Here, the IP address and streaming Port of RPi is added in the Port mapping window of WiFi router. Thus, the RPi's IP address and Port is mapped to router's IP address and Port. Live video can be watched from anywhere using Router's IP address and Port. Video will be saved in RPi for future reference and it will be deleted once it is sent to user by email.

IV. RESULTS OF IMPLEMENTATION

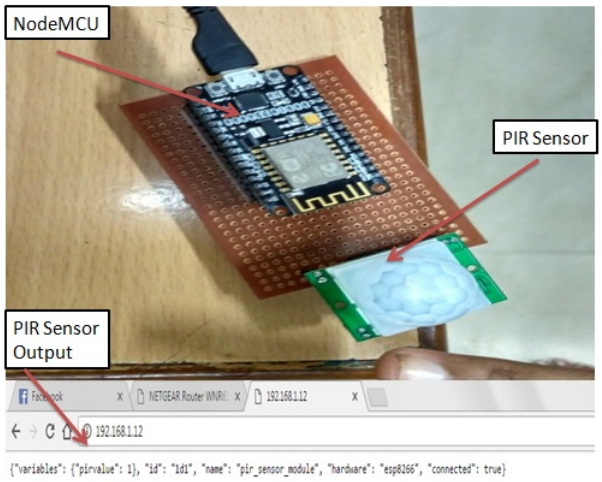

Fig. 6. Wireless PIR Sensor Node

Fig. 6 shows the PIR sensor node implemented using IoT module (NodeMCU). The output obtained from the PIR sensor is shown on a webpage. The IoT Module is powered using a normal USB 5V supply. The sensor gets 5V supply from MCU and it gives a logical output to the digital pin of MCU. In the presence of human being, it gives logic high at its output pin and it is indicated in webpage shown in Fig. 6.

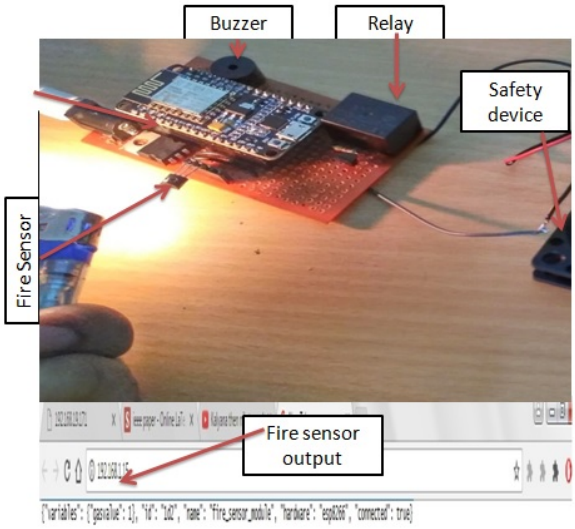

Fig. 7. Wireless Fire Sensor Node

Fig. 7 shows the fire sensor node developed using IoT module. The sensor status of fire sensor node is shown on the corresponding webpage. The output of sensor is connected to analog pin of NodeMCU. NodeMCU reads the analog output of sensor and makes a digital pin high when sensor senses fire. Buzzer and transistor relay driver circuit are connected to that digital pin. Thus, buzzer buzzes and safety device gets activated when sensor detects fire.

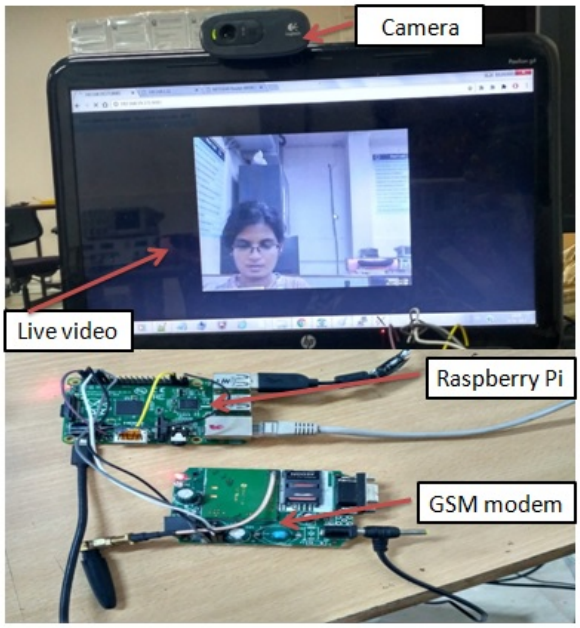

Fig. 8. Surveillance Controller System

Fig. 8 shows the surveillance controller system implemented using Raspberry Pi. It includes buzzer, GSM Modem and WebCam. Raspberry Pi is powered by 5V adapter and GSM is powered by 12V adapter. The desktop of Raspberry Pi is accessed remotely from putty software which is installed on laptop.

The screenshot of the live video is also shown in Fig. 8. User seeks surveillance on webpage using WiFi router's IP address. This system is useful for the owner to get a remote view of his home and to keep an eye on his valuables.

Fig. 9 shows the sensor status obtained at the master node section. The sensor output crawled from webpage is shown in python shell. If the PIR sensor data crawled from webpage shows a logic high value, then camera is activated, image is captured and sent to the user. After that, motion software is triggered, video is recorded and notification is send to user via AT commands. If the fire sensor data crawled from the webpage gives a logic high value, then GSM is activated and SMS and call notification is send to user.

Fig. 10 shows the screenshot of received email with the picture of intruder as attachment.

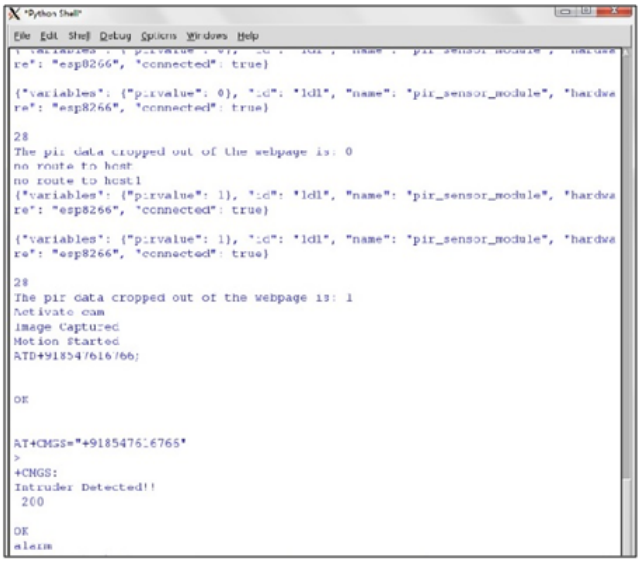

Fig. 9. Python Shell

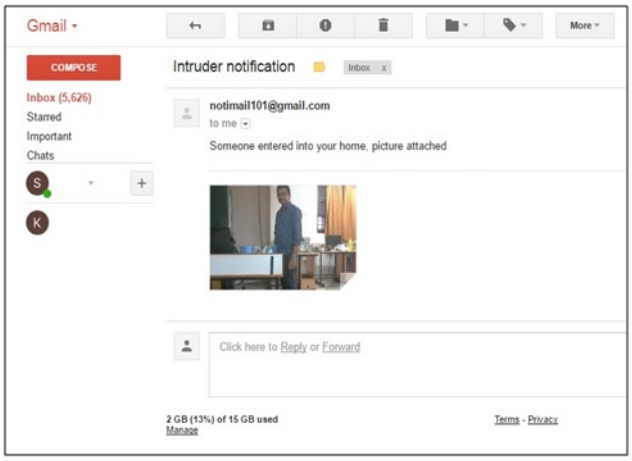

Fig. 10. Screenshot of Email

V. ADVANTAGES OF SYSTEM

Low cost: The use of IoT module reduces the cost of wireless sensor nodes. In normal case, WSN will have a sensor, a microcontroller and a wireless transmitter module. At the receiver section, a wireless receiver module will be there. The function of microcontroller and a wireless transmitter module can be achieved by making use of a single IoT module. Since the receiver is connected to WiFi, wireless receiver module is not needed. Thus many nodes can be added and the cost of the entire system can be reduced.

Compact: Since size of IoT module is very small, it is very easy to handle and thus it makes the entire system compact.

Long Range: IoT module gives extremely good working range. For long range communication, we prefer this module.

We are able to communicate with the module upto a distance of 400m.

Worldwide monitoring and control: The use of WiFi in embedded system makes the system globally controllable and accessible.

VI. CONCLUSION

In this paper, we have designed and developed a real time surveillance system using IoT module and Raspberry Pi. It is an active surveillance system which will alert the user when the event happens. Intruder and fire detection are the prime features of the system. Live video streaming is an additional advantage of the system. We have created web servers which helps the user to view the sensor status and the live video. This system also sends intruder's picture and the captured video to the owner by email. The use of NodeMCU makes the system cost effective, portable and compact. Most of the existing surveillance systems are costly and common people may not spend a lot for such systems. This system is designed with an aim that it can be used for all kind of people since security of every one's home should not be left behind.

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