DESIGN AND IMPLEMENTATION OF A ZIGBEE-ENABLED WIRELESS SMART HOME SECURITY SYSTEM

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ABSTRACT:
With the rising demand for intelligent and remote surveillance, smart home security systems have become a key aspect of modern living. This paper presents the design and implementation of a Zigbee-enabled wireless smart home security system, which ensures real-time monitoring, low power consumption, and reliable communication between sensors and a central control unit. The proposed system integrates motion sensors, door/window magnetic sensors, smoke detectors, and a microcontroller-based gateway connected via the Zigbee communication protocol. When a security breach or emergency is detected, alerts are sent to the homeowner's mobile device or monitoring station via a connected interface. Zigbee's low-power mesh networking capabilities make it ideal for home environments, allowing easy scalability and multi-room coverage. The system was tested under various scenarios, demonstrating high accuracy, fast response time, and robust wireless communication. This study confirms that Zigbee-based wireless networks offer an efficient and secure solution for home automation and intrusion prevention.

I.INTRODUCTION

Home security has evolved significantly with the advent of Internet of Things (IoT) and wireless communication technologies. Traditional wired security systems are often costly, complex to install, and difficult to scale or upgrade. In contrast, wireless smart home security systems offer flexibility, real-time monitoring, and ease of integration with other IoT devices. Among various wireless protocols, Zigbee has emerged as a suitable choice for home automation due to its low power consumption, mesh networking capability, and reliable communication over moderate distances.

The increasing cases of theft, unauthorized access, and fire hazards in urban residential areas have emphasized the need for a cost-effective and dependable security solution. This research proposes a Zigbee-based wireless home security system that connects multiple environmental and intrusion detection sensors to a central microcontroller, enabling users to monitor their homes in real-time through mobile or web-based platforms.

The objective of this study is to design, develop, and evaluate a smart security architecture that can detect abnormal events such as unauthorized entry, motion in restricted zones, or the presence of smoke or fire. The system is designed to alert homeowners immediately through wireless alerts, while maintaining low power consumption, easy scalability, and seamless integration into existing smart home infrastructures.

This security system required for:

- Empty Homes
- Banks
- Industries
- Many more

Suppose, There is no one in the house or bank and someone came with bad intentions and try to temper the lock or try to break the door then this system will automatically came in action and lock the door permanently, cameras will start to take picture of the person standing outside the door and send these picture to the owner and will wait for the response of the owner and then work accordingly.

Smart home could also be called “Automated Home”.

Home security system

Zigbee technology was came to be known in 2004, since then it is benefice several networking systems. The main function of the zigbee device is to create network by connecting the input sensors and Electro-Mechanical relays, Motors and Alarms as output.

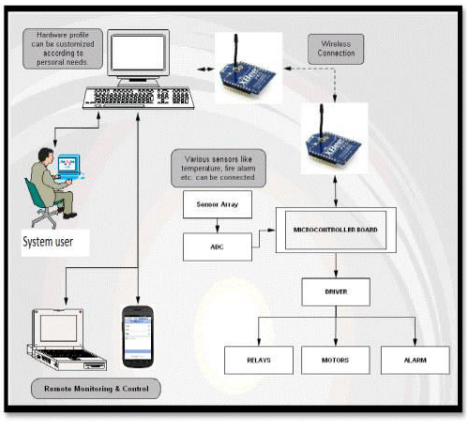

Fig.1: System Architecture

Fig. 1 shows the basic architecture of the security system.This is the proposed architecture for Zigbee based security system. Here, Sensors are used as an input devices. These inputs are cameras, infrared motion sensors and SIM 900A GSM module. These sensors will sense the presence of the person trying to enter into the house or banks, if he is a authorized person then there will be no problem but if the person is unauthorized then the system will barred the entrance by locking the doors. Here,In this system some drivers are used as an output devices. These outputs are relays, motors, SIM 900 GSM Module. The main purpose of the proposed design is to use of technology for enhancing the security for upcoming threats.

Here, We have used Zigbee technology because it is reliable, low power consumption, low data rate, supports up to 65,000 nodes in a network, can automatically established its network and uses small packets compared with WiFi and Bluetooth.

This system consist of two modules-

- Entrance Sensing Module
- Control Module with Relay Controlling Circuits.

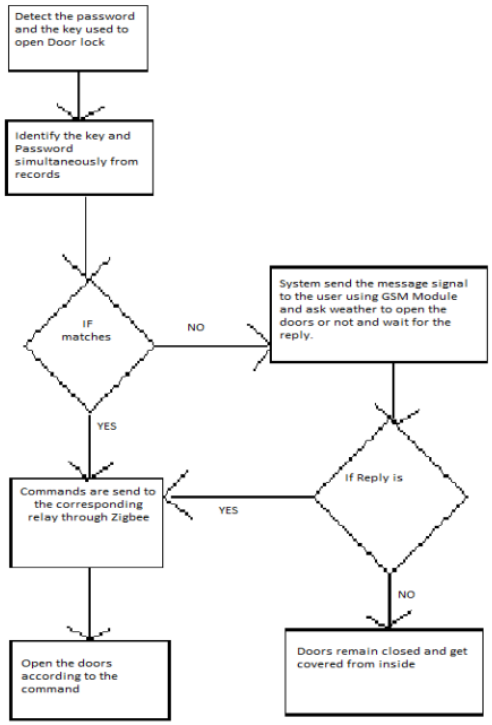

Fig. 2 Flow chart of the system

Fig. 2 shows the sequence of working of the system. As the device will ask for the password and the door key, if key and password is correct then door will get open and the person can get into the house otherwise, if, any of the two is incorrect then door will not open and send a message signal to the owner through GSM Module. After the reply of owner, the device will work accordingly.

The devices used are as follows-

1. **Micro-controller (ATMEGA168):-** ATMEGA168 is a member of AVR family. AVR is a family of micro-controllers developed by Atmel. THis is modified Harvard architecture 8-bit RISC single chip micro-controller. It is high-performance, Low-power Microchip RISCbased CMOS 8-bit micro-controller combines 16KB ISP flash memory with read-while-write capabilities,512B EEPROM, 1KB SRAM,23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and

external interrupts, serial programmable USART, byte-oriented 2-wire serial interface, SPI serial port, 6-channel/10-bit A/D converter,programmable watchdog timer with internal oscillator and five software selectable power saving modes. It has 32 pin count and have operating voltage range of 1.8V to 5.5V.

This AVR microcontroller have internal EEPROM for semi permanent data storage. This EEPROM maintain data stored in it even after the removal of power. The data stored in this micro-controller retains for almost 100 years at 25°C, that means for a very long time.

One of the important feature of this AVR micro-controller is that It has Flash, EEPROM and SRAM integrated on a single chip.

2. Zigbee RF Communication:- Zigbee is an opne global standard based on the IEEE 80.15.4 standard with low-power, low-cost, wireless mesh networking. Zigbee represents a network layer above the 802.15.4 layers to support advanced mesh routing capabilities.

Zigbee nodes are of 3 types-

- **Coordinator:-** A node that has the unique function of forming a network. The coordinator is responsible for establishing the operatingchannel and PAN IDfor an entire network.
- **Router:-** A node that creates/maintains network information and uses this information to determine the best route for data packet. A router must join a network before it allows other routers and end devices to join.
- End devices must always interact with their parent to receive or transmit data. They are intended to sleep preriodically and therefore have no routing capacity. An end device can be source or destination for data packets but cannot route packets.

Zigbee Security:- Zigbee supports various level of security depending upon the needs of the application.

Security provisions include:-

128 bit AES encryption

- Two security keys that can be preconfigured or obtained during joining.
- Support for a trust center
- Provision to ensure message integrity, confidentiality and authentication.

The Xbee standard supports three security modes:

Residential security:- It requires a network key be shared among devices.

Standard security:- It adds a number of optional security enhancements over residential security including an APS layer link key.

High security:- It adds entity authentication and a number of other features not widely supported.

Key features of Zigbee Technology:-

- Cost effective
- Highly reliable and secure.
- Supports multiple network topologies e.g. Point to point, point to multi point, mesh network and cluster tree.
- The speed of data rate is 250 Kbps.
- Low latency
- Long battery life due to low duty cycle.
- It supports 65000 nodes per network.
- Has 128 bit AES encryption for secure data connections.
- Direct Sequence Spread Spectrum provides excellent performance in Signal to Noise ratio environment.

3. GSM Module SIM 900A:- GSM Modem RS232 is built with dual band GSM engine. SIM900A works on frequencies 900/1800 MHz. The Modem is coming with RS232 interface. The baud rate is configurable from 9600-115200

through AT command. The GSM modem is having internal TCP/IP stack to enable you to connect with internet via GPRS. It is suitable for SMS, Voice as well as Data transfer.

A GSM modem duly interfaced to the Micro-Controller through the level shifter IC Max232. The SIM card mounted GSM modem upon receiving digit command by SMS from any cell phone send that data to the micro-controller through serial Communication. While the program is executed, the GSM modem receives command 'STOP' to develop an output at the micro-controller, the contact point of which are used to disable the ignition switch. The command so send by the user is based on an intimation received by him through the GSM modem 'ALERT' a programmed message only if the input is driven low.

Comparision of Zigbee with related technologies:-

Technology	Bluetooth	WiFi	Zigbee
Frequency	2.4GHz	2.4GHZ 5GHz	868MHz 915GHz 2.4GHz
Modulation	FHSS	QPSK COFDM QAM	BPSK O-QPSK
Error Control	CRC(16 bit)	CRC(32 bit)	CRC(16 bit)
Range	10m	100m	10m-100m
Network Size	8	2007	64000
Power Consumption	Medium	High	Very Low

Table-1, Comparision of Bluetooth,WiFi and Zigbee

II. EXPERIMENTAL RESULT

Now analyze the implemented system on both the qualitative measures and quantitative measure with some of the experiments.

To analyze the system, we are going to observe the time taken by the system to respond on different occasions with right and wrong keys and Password. The door was opened with right keys and password 10 times and with either wrong key or password or both 10 time.

	Avg.Time taken by system is sending message(ms)	Avg. Delay after reception of message by system(ms)	Time taken in (if) opening the door(ms)
With right key and Password	N/A	N/A	1230
Without right key and password	1140	470	1610

Table-2, Responce time of the system in different situations

Now the average time taken by system in both sending message to the owner and receiving and opening the door is given is table 2.

In this experiment, We have taken an assumption that there is no problem in GSM operator network and as we send a message it got received to the other one and owner replies immediately.

Previous one was quantitative analysis but when we talk about the quality then in all the 10 time when we uses wrong key or password, system do not open the door and send the message to the owner all the 10 times.The avg time taken in getting message by owner is about 2 min. 40 sec.

III. CONCLUSION

The Zigbee-enabled wireless smart home security system presented in this study offers an efficient, low-cost, and scalable solution for safeguarding residential environments. The system successfully integrates various sensors to detect motion, intrusion, and environmental hazards, all while maintaining robust communication through Zigbee's mesh network capabilities. The use of microcontrollers and wireless transmission reduces wiring complexity and supports real-time event detection and notification.

Experimental results validate the system's reliability, fast response time, and low energy usage, making it suitable for modern smart homes. The modular design also allows easy expansion with additional sensors and supports integration with mobile applications for enhanced user interaction.

In conclusion, the proposed Zigbee-based home security framework demonstrates the feasibility of using wireless sensor networks for effective domestic surveillance and safety. Future improvements may include AI-driven intrusion analysis, cloud-based data logging, and integration with other home automation systems for a comprehensive smart living experience.

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