Smart alarming system using embedded controller, ZigBee communication and Global System of Mobile (GSM)

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Abstract: - This paper presents a smart alarming system applying embedded controllers, ZigBee communication, and GSM knowledge. The method allows users to wirelessly monitor their properties, such as companies and houses, through Short Service Message (SMS) alerts. The primary unit and its subunits are the two basic parts of the system. As the primary hub, the main unit is equipped with two microcontrollers, a motion sensor, a ZigBee module, and a GSM interface. For monitoring, sub-units covering a motion sensor, ZigBee module, and microcontroller can be placed in different locations. These sub-units use a Point-to-Multipoint system (PTMS) to wirelessly connect with the main unit. When a motion sensor in a monitored area detects movement, it sends an alarm and wirelessly communicates the address of the relevant room to the main unit. The user receives an SMS alert with the room's address as soon as the main unit, which is connected to GSM, goes off Additionally, one of the sub-units can be linked to a laptop within the same building, facilitating comprehensive room monitoring. This system offers users a flexible and efficient solution for remote premises monitoring.

Key-Words: **-:** Smart Alarming; Embedded Controller; ZigBee communication; Mobile

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1 Introduction

The field of alarms and sensors is very developed nowadays. New and improved types of alarms and sensors are always coming into the market and the choice between different types seems quite difficult. Despite the baffling selection, one should understand that all alarm systems have a very similar basic structure and work in accordance to the same principals. An alarm system consists of a main control box to which various sensors are connected. When the sensors identify a break-in, they send out a signal to the control box, which, in turn, sounds the alarm or performs other predefined tasks such as calling the police or a security company, turning on certain lights etc. This project is intended for people who are interested in installing an alarm system as well as those interested in complete protection of their properties. The home security market today offers a wide range of products; from DIY alarm systems for only a few tens of dollars, to encompassing and advanced systems costing several thousands of dollars for it to be installed by professionals. If anyone decides to install an alarm system, the key to choosing a system is to understand the security needs of his home, and taking into account his home's unique structure. Different sensors are suited to different areas; there are door sensors, window sensors, hallway sensors, closet sensors, drawer sensors and so forth. Even if the security company is the one installing the alarm system in anyone's home, previous knowledge of alarm systems will allow him to fully understand the advice he receives from the security company, as opposed to reaching these decisions blindly.

Alarms have existed since the first automatic control systems were implemented. Initially, alarms were hard-wired to some form of enunciator, and because of the considerable work involved in implementing any one alarm, there generally were only a few alarms on one piece of equipment, and at most one or two hundred alarms in any control house [1-4]. And the ones that were implemented were likely thought out fairly well, both in determining what hazardous condition the alarm was detecting, and what the response should be to the alarm. But, as anyone who knows the comparison between analog systems to a modern computerized system will tell, the great disadvantage of an analog system is that it lacks flexibility – even a modest change requires a significant capital expenditure and time commitment. In contrast, adding an alarm on a computerized control system is as simple as flipping a bit, and a modern distributed control system (DCS) has an almost infinite capacity for alarms, and for displaying these alarms in one format or another. And, as could be expected, when something is cheap it results in a host of other problems that were unanticipated by the designer (such as greenhouse gases or insufficient exercise caused by cheap gasoline).

Figure 1.1 Wireless alarming systems Diagram

Of course it's worse for the operational staff, who are the ones facing the real-time onslaught of alarms, even when the process is in relatively stable condition. In our system we used a wireless alarming network, you can avoid the complicated drilling, hammering and installation process often associated with hardwired systems. You have to put a distribution to the units in the building. And these entire units are connected according to the Point-to multipoint system. Figure 1 illustrates how our system works.
Creating wireless networks can be done using a variety of RF protocols. Some protocols are proprietary to individual vendors; others are industry standards. This Application Note will explore the ZigBee protocol [5,6] industry standard for data transmission, and the IEEE 802.15.4 protocol on which it was buil [7-9]. The definition of the frequencies used, the bandwidth it occupies, and networking features unique to this protocol.

2 Protocol 802.15.4

The Protocol 802.15.4 is a standard for wireless communication put out by the IEEE (Institute for Electrical and Electronics Engineers) [10]. The IEEE is a technical professional association that puts out numerous standards to promote growth and interoperability of existing and emerging technologies. Key aspects of Protocol 802.15.4:

1. **Physical Layer (PHY)**:

- Operates in the 2.4 GHz ISM (Industrial, Scientific, and Medical) band or sub-1 GHz bands (such as 868 MHz in Europe or 915 MHz in the United States).
- Supports multiple data rates, ranging from 20 to 250 kbps, depending on the frequency band used.

- Utilizes Direct Sequence Spread Spectrum (DSSS) modulation or Offset Quadrature Phase Shift Keying (O-QPSK) modulation for transmission.

2. **MAC Layer (Media Access Control):**
   - Implements the CSMA-CA (Carrier Sense Multiple Access with Collision Avoidance) protocol for channel access, which helps avoid collisions by sensing the channel before transmission.
   - Supports different network topologies such as star, peer-to-peer, and mesh networks.
   - Provides mechanisms for addressing, frame validation, acknowledgments, and frame retries to ensure reliable communication in low-power and noisy environments.
   - Defines different frame types for various purposes, including data frames, acknowledgment frames, beacon frames, and command frames.

3. **Network Topologies:**
   - Supports various network topologies including:
   - Star Topology: Devices communicate with a central coordinator.
   - Peer-to-Peer Topology: Devices communicate directly with each other without a central coordinator.
   - Mesh Topology: Devices can communicate with each other via intermediate nodes, forming a mesh network.

4. **Energy Efficiency:**
   - Designed for low-power operation, making it suitable for battery-operated devices and applications requiring long battery life.
   - Utilizes mechanisms such as duty cycling, low-duty listen modes, and low-power sleep modes to conserve energy.

5. **Applications:**
   - 802.15.4. Is commonly used in various applications including home automation, industrial monitoring and control, healthcare, smart meters, and environmental monitoring.
   - It provides the underlying connectivity for protocols like Zigbee, Wireless HART, and Thread, which build upon the 802.15.4 standard to offer higher-level functionalities and services.

Overall, Protocol 802.15.4 is a foundational standard for enabling low-power, low-cost, and reliable communication among devices in wireless personal area networks. [11, 12].

3 ZigBee

ZigBee is a protocol that uses the 802.15.4 standard as a baseline and adds additional routing and networking functionality [2,4,5,6]. ZigBee is designed to add mesh networking to the underlying 802.15.4 radio. Mesh networking is used in applications where the range between two points may be beyond the range of the two radios located at those points, but intermediate radios are in place that could forward on any messages to and from the desired radios. If the application strictly needs to communicate in a point-to-point or a point-to-multipoint fashion, 802.15.4 will be able handle all the communications between your devices and will be simpler to implement than trying to use a module with ZigBee firmware to accomplish the same goal. ZigBee is necessary if you need to use repeating or the mesh networking functionality as an example. Figure 2 shows how to transmit data from point A to point B, and the distance is too far between the points. The message could be transmitted through point C and a few other radios to reach the destination. Another feature of ZigBee is its ability to self-heal. If the radio at point C was removed for some reason, a new path would be used to route messages from A to B. Devices in the ZigBee specification can either be used as End Devices, Routers or Coordinators Routers which can also be used as End Devices. Since the ZigBee protocol uses the 802.15.4 standard to define the PHY and MAC layers, the frequency, signal bandwidth and modulation techniques are identical [13-19]

4 Microcontroller

A highly integrated chip that contains the component comprising a controller in our project. Typically, this includes a CPU, RAM, some form of ROM, I/O parts, and timers. Unlike a general-purpose computer, which also includes all of these components, a microcontroller is designed for a very specific task to control a particular control system and other applications. As a result, the parts can be simplified and reduced, which cuts down on production costs. Microcontrollers are sometimes called embedded microcontrollers, which just mean that they are part of an embedded system that is one part of a larger device or system. Also, a microcontroller is a computer on a chip optimized to control electronic devices. It is a type of microcontroller emphasizing self-sufficiency and cost-effectiveness, in contrast to a general-purpose microprocessor, the kind used in PCs. A typical microcontroller contains all the memory and I/O interfaces needed, whereas a general purpose microprocessor requires an additional chip to provide these necessary functions or operations to improve the control system. In this paper we used two of PIC16F877A connected wireless. We can declare it as the brain of our project.

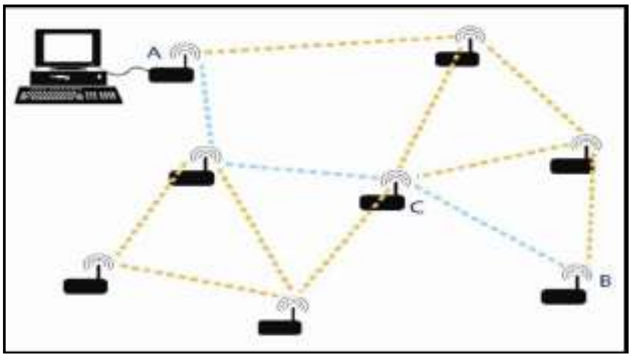

Figure2: Example of ZigBee networks

4.1 Why a Microcontroller is needed

The use of the first microcontroller took place in 1933 and from that time it started to spread until it became difficult to work in the electronic field without using microcontrollers. And these control lings are present inside many systems that we use them in everyday life for example in the obstacle avoidance car system we find that the brakes and the speed fixative take place in controlling it by microcontrollers, and if we looked at a microwave oven in the kitchen we can find inside it a microcontroller for the control of the timing and the heat according to the choices that we request at the cooking. And the examples on the institutions that are found inside it a microcontroller are: telephones, the scout, the refrigerators, and the washing machines. Microcontrollers can be used with sensors, actuators, also applications as remote controls and robot controlling. Its ease of programming and understanding made this application so wide [8].

4.2 Microcontroller PIC16F877A

The PIC is the brains of the device (robot) and controls communication between it and the compact flash card, the LCD display, and other inputs and outputs. PIC (Peripheral Interface Controller) is the IC which was developed to control peripheral devices, dispersing the function of the main CPU. When comparing it to the human body, the brain serves as the main CPU, while the PIC shares a role equivalent to the autonomic nervous system. PIC16F877A is one of the most commonly used Microcontrollers, especially in automotive, industrial, mobile, and consumer applications. PIC16F877A can be used to convert an analog input signal to a digital number represented in 10 bits, convert this HEX number to an equivalent decimal BCD value, and display this value on an LCD. Additionally, it is powerful (200 nanosecond instruction execution), easy-to-program (only 35 single word instructions), and is a CMOS flash-based 8-bit microcontroller. The PIC16F877A features 256 bytes of EEPROM data memory, 5 channels of 10-bit analog-to-digital (A/D) converter, 2 additional timers, and 2 capture/compare/PWM functions, which are used to control the velocity of motion

4.3 The PIC Microcontroller

The Microcontroller in our project is connected with a motion sensor to read any motion that is detected by the sensor. MCU connected with the ZigBee Module via serial port for transmitting the data wirelessly to the main unit. In the main unit we used two Microcontrollers, because we needed two serial ports. One is connected with the ZigBee module and the other is connected with GSM modem as shown in Figure 3.

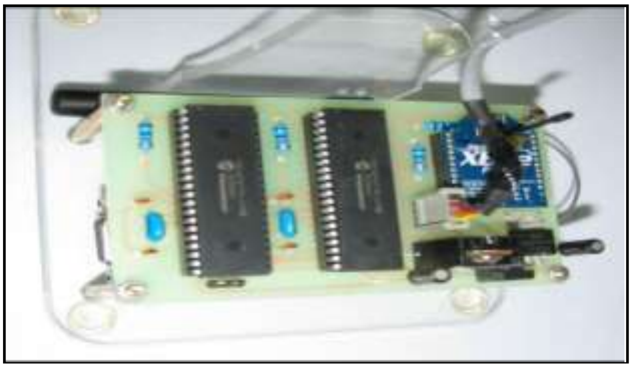
Figure 3: Two Microcontrollers used in our project

4.4 The GSM system

We used the GSM TC35 in our project to send SMS to users for alarming when one of the motion sensors detects any motion. The GSM is connected to the Microcontroller via serial port as shown in Figure 4 below. We used the AT command to program it through the Microcontroller. The SMS which will be sent to the user contains the address of the room which has strange motion.

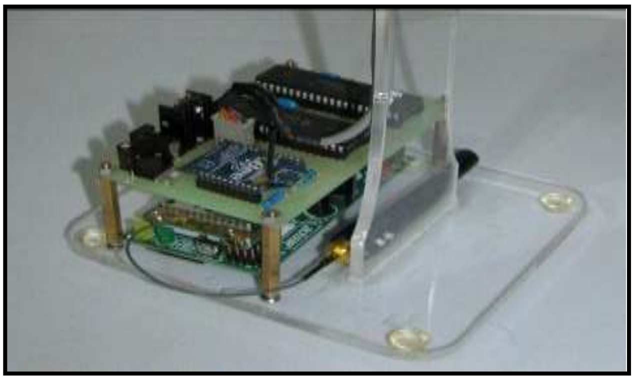
Figure 4 GSM TC35 is connected with Microcontroller

5 Design and Implementation

The present work consists of two parts, the first is a subunit that consists of a ZigBee module, a Microcontroller and a PIR Motion sensor. The second is called the main unit which consists of the ZigBee module, GSM and Microcontroller. One of the subunits is connected with a laptop or PC for monitoring. Figure 5 below, is a simplified block diagram of the system, showing the basic sub blocks components.

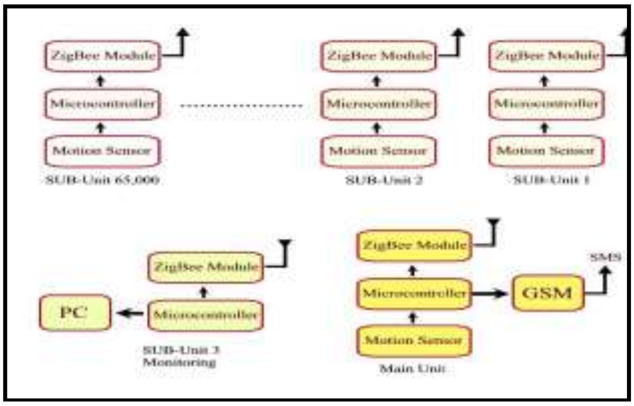

Figure 5 Block Diagram of the system

5.1 The Sub-Unit

In the sub-unit the motion sensor is connected with a Microcontroller which will read a signal from it, when the PIR detects any motion the Microcontroller will send the address of the sub-unit via ZigBee Module to the main unit. Figure 6 shows the schematic circuit of the sub-unit. Users can use a lot of sub-unit (up to 65000 nodes) and place them in the rooms which need to be monitored.

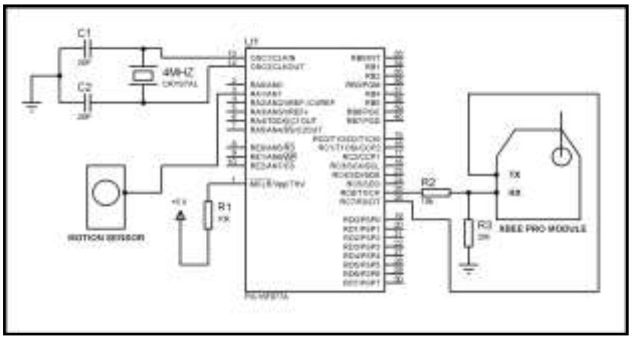

Figure 6 The schematic circuit of sub-unit

5.2 The Monitoring Unit

For online monitoring, we connected one of the subunits with a PC or Laptop for monitoring. We have used a USB-To-Serial converter and connected the ZigBee module with the laptop as shown in Figure 7.

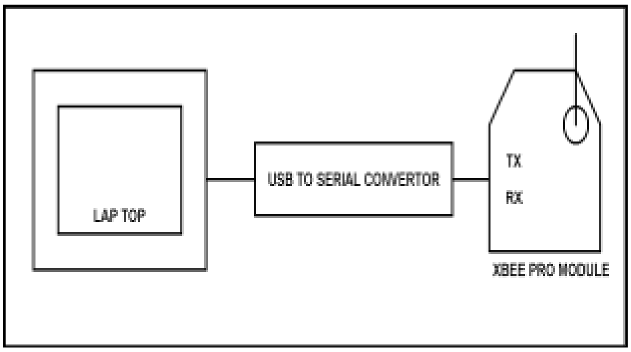

Figure 7 The schematic circuit of Monitor unit

5.3 The Main Unit

In the main unit we used two Microcontrollers; the first is connected with the ZigBee module that will receive data from all sub-units. The second is connected with a GSM module that will send SMS to the user to alert him about the motion in the room. The Figure 8 below shows the schematic circuit of the main unit.

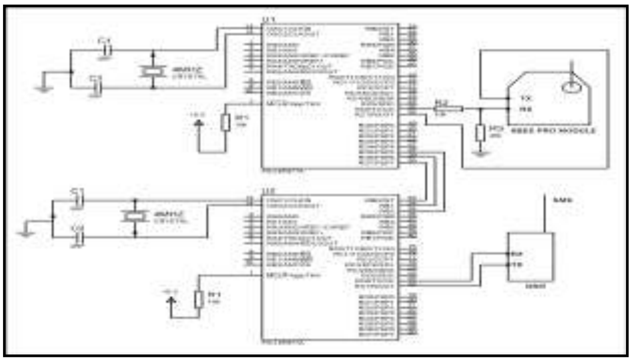
Figure 8 The schematic circuit of main-unit

6 Statistical results

statistical results that could be relevant for evaluating the performance of a smart alarming system using embedded controller, ZigBee communication, and GSM:

1. Response Time: Measure the average time it takes for the system to detect an alarm trigger and send a notification via GSM. This could include the time from sensor detection to alert transmission.
2. False Alarm Rate: Determine what proportion of sounds are false alarms. This aids in evaluating the system's reliability and efficacy in precisely identifying genuine threats.
3. Detection Accuracy: Assess how well the system distinguishes between missed alarms and real threats. This could be expressed as the proportion of correctly identified alerts among all actual alarm events.
4. Battery Life: Evaluate the system's embedded controller nodes' battery life. This might entail calculating how long something can run continuously before needing to be replaced or recharged.
5. Communication Reliability: Assess the ZigBee-based embedded controllers' communication reliability with the GSM network. Metrics including delay, signal strength, and packet loss may be included.
6. Scalability: Evaluate the system's capacity to grow as more sensor nodes or deployed units are added. Testing network performance at different node density and loads may be part of this.
7. Cost-effectiveness: Examine how much installing and maintaining the system will cost in comparison to more established alarm systems or non-traditional technology. This covers the purchase price of the hardware up front, continuing maintenance, and any GSM service subscription payments.
8. customer happiness: Get customer comments regarding their setup experience, interface usability, and general level of happiness with the security offered by the system.

These figures can offer insightful information on the smart alarming system's functionality, dependability, and user satisfaction, which can be used to pinpoint areas in need of enhancement and optimization.

7 Conclusion

In conclusion, the development of a smart alarming system utilizing embedded controllers, ZigBee communication, and GSM technology presents a significant advancement in remote premises monitoring. This system provides users with the capability to wirelessly monitor their premises, such as homes and businesses, through SMS alerts triggered by motion detection. By employing a main unit and sub-units interconnected via ZigBee communication, the system ensures comprehensive coverage and efficient data transmission. The integration of GSM technology enables real-time alerts, enhancing the system's effectiveness in notifying users of potential security breaches.

Future Research Directions: While the presented smart alarming system demonstrates promising capabilities, there are several avenues for future research to further enhance its functionality and applicability:

1. Integration of Advanced Sensors: Explore the incorporation of advanced sensors beyond motion detection, such as temperature, humidity, and gas sensors, to enable broader environmental monitoring capabilities. This expansion would provide users with comprehensive insights into their premises' conditions beyond security concerns.
2. Energy Efficiency Optimization: Investigate methods to optimize the energy consumption of the system components, particularly the embedded controllers and wireless communication modules. Implementing energy-efficient protocols and algorithms can prolong the system's operational lifespan and reduce maintenance requirements.
3. Enhanced Data Security: Enhance the data security measures implemented within the system to safeguard sensitive information transmitted via ZigBee and GSM networks. Research encryption techniques and authentication protocols to mitigate potential security vulnerabilities and ensure user privacy.
4. integration with IoT Ecosystems: To facilitate smooth interoperability with other smart devices and platforms, investigate integration opportunities with larger Internet of Things (IoT) ecosystems. Through this link, customers will be able to develop automation routines that are specifically

matched to their needs, increasing the system's versatility.

5. Enhancements to the User Interface and Experience: Pay close attention to improving the system's user interface and experience, particularly with regard to SMS notifications and mobile application design. In order to expedite setup and configuration procedures and increase system accessibility for a broader user base, incorporate user feedback mechanisms and intuitive controls.

The smart alarming system can develop into a more reliable and adaptable remote premises monitoring solution by pursuing these research avenues, meeting the changing demands of both residential and commercial customers.

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Declaration of Generative AI and AI-assisted Technologies in the Writing Process

During the preparation of this work the authors used chatpgt.com// service in order to improve quality of work process. After using this tool/service, the authors reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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Ibrahim Al-Edwan Anwar Al-Mofleh Omar. Badran: provided the conception and design of the study, acquisition of data, analysis and interpretation of data, drafting the article, revised it critically for important intellectual content, and final approval of the version to be submitted

Ahmad Awad: supplied the acquisition of data, drafting of paper;

Mohamad Alqadi: supplied the design of study, analysis and interpretation; supplied the acquisition of data.

Naim Alkawaldeh: was responsible for the article critically for important intellectual content;

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