



Emergency Response Notification for Indoor Situations using ZIGBEE

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ABSTRACT: Today's world we are faced with many different types of emergencies in the indoor environment. Response to such emergencies is critical in order to protect resources including human life. In this paper, we present an emergency response system which is easy to deploy and can report the emergency to the users in various forms, such as messages on a computer screen, SMS on user cell phones and many more. Due to this flexibility of reporting, low cost and easy of deployment, wireless sensor network (WSN) using ZIGBEE, emergency response systems will be the preferred emergency response systems of the future. We show a design for a WSN emergency response system using temperature sensors as a proof of concept. Comparison to other emergency response systems within campus is also drawn out.

Keywords: Component; Emergency response, WSN, ZigBee, Emergency Services, Networks, Sensors.

I. INTRODUCTION

Today's world we are faced with increasingly many types of emergencies in our environments. One example which stands out is the gun violence which has plagued our universities and communities alike. In addition, institutions with poor infrastructure may not be able to minimize loss of resources and human life in times of natural catastrophes. The objective of this project is to design a wireless network using Zigbee to respond to any emergency and inform appropriate individuals in a timely and cost effective manner. The project further aims to enable ease of installations of variety of sensors and networking possibilities with a variety of networks such as CISCO messaging client or a desktop program in order to make messaging easily integrated with existing systems.

II. WIRELESS SENSOR NETWORK

A wireless sensor network (WSN) is as a wireless network which consists of equally distributed autonomous devices using sensors capable of monitoring the physical or environmental conditions such as temperature, sound, vibration, pressure, motion or pollutants, at various different locations especially for buildings in campus [1-3]. In addition to one or more sensors, each node in a sensor network is typically equipped with a radio transceiver or other wireless communications device, a small microcontroller, and an energy source, usually a battery [1]. The cost of sensor nodes is similarly variable, ranging from hundreds of dollars to a few cents, depending on the size of the

sensor network and the complexity required of individual sensor nodes [2]. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and bandwidth [3].

III. CURRENT EMERGENCY SYSTEMS

Before ZigBee based wireless sensor networks are tested for their efficacy, we first present existing technology in place to do emergency response. The efficacy of ZigBee based wireless sensor networks is studied over and above existing systems.

A. Wireless Emergency Notification System

Wireless Emergency Notification System (WENS) by Inspiron Logistics uses True text messaging to notify people on campus of an emergency. True text messaging or SMS is the top recommendation for implementing a campus-wide notification solution.

In the WENS system an authorized person chooses a group to notify, types the message and hits send [7]. The WENS system tries every 5 seconds, indefinitely, until the text message is delivered. WENS can track each and every text message with a delivery receipt and subsequent report [7]. This gives school officials a way to know that the message was delivered.

The WENS system has a proprietary service called an Imaging and Video Delivery System (IVDS). IVDS provides the campus community with the ability to send images and video to campus police [7].

B. Internet

By using the internet the alerts can be updated on the websites of a campus (monitored area), which has the various procedures to be taken in case of emergency.

C. E-mail

All users who are registered at the website of campus (monitored area) will receive emergency alerts without any charge.

D. Telephone

A toll-free and a local telephone number can be established so that you can call to receive such as 100 police number and more. In the event of emergency, other options, including call-centers, media alerts, and other pre-recorded messages may be available using the same toll-free number.

IV. RESPONSE TIME

Based on the study from WENS website [7], in the event of an emergency it will take four minutes after the occurred emergency for the administrators to issue an alarm, it then takes another two minutes for all subscribers of the system to be notified of the emergency. The response time of campus emergencies depends on current load, emergency type and how quickly it is detected. Effort is being made to reduce response time as short as possible such as increase patrol of campus police, easy emergency reporting platforms and installation of smart sensors.

Given below are some key factors we look into, as we develop a wireless emergency notification network:

- Effectiveness of the sensors to detect an emergency.
- Transmission delay between sensing and reporting of information from the sensor to the central processing unit, personal area network coordinator (PANC).
- Threat validation delay once the emergency has been detected.

V. IMPLEMENTATION PLAN

The project will utilize open hardware for realizing its goals. The eventual goal is for the project to use PC's as the 'sink' in order to collect data from various sensors and provide them in a user friendly fashion. Client software can be developed and can be programmed to read out messages or pop out notifications that are deemed as emergency based on a preexisting criterion. Our project will focus on fire emergency and temperature sensors are used to conduct the feasibility study of the system.

VI. IEEE 802.15.4 PHY AND MAC STANDARD

IEEE 802.15.4 standard offers an implementation for the lower layers, PHY and MAC, for a typical WSN as discussed in [6]. 802.15.4 Focuses mainly on low-cost, low-speed communication between devices. The basic IEEE 802.15.4 framework defines a 10-meter communications area with a maximum transfer rate of 250kbts/s. It is the basis for the ZigBee specification, which further attempts to offer a complete networking solution by developing the upper layers which interface with the IEEE 802.15.4 MAC [4].

A. 802.15.4 Standard

The protocol structure of 802.15.4 contains PHY and MAC layers only [1]. The upper layers are user defined.

1. Physical layer:

The physical layer (PHY) provides the data transmission service, as well as the interface to the physical layer management entity. It manages the physical RF transceiver and performs channel selection and energy and signal management functions.

The PHY is responsible for the following tasks:

- Activation and deactivation of the radio transceiver.
- Energy detection (ED) within the current channel.
- Channel frequency selection.
- Data transmission and reception.

2. Medium access control (MAC) layer:

The MAC layer is responsible for point-to-point delivery between nodes. Besides the data service, it offers a management interface and itself manages access to the physical channel and network beaconing. It also controls frame validation, guaranteed time slots (GTS) and handles node associations.

The MAC sub layer handles all access to the physical radio channel and is responsible for the following tasks:

- Generating network beacons if the device is a coordinator
- Synchronizing to network beacons
- Supporting PAN association and disassociation
- Supporting device security.



Fig. 1. Components and interfaces of the MAC sublayer.

B. ZigBee

ZigBee is a specification for a suite of high level communication protocols using small, low-power digital radios based on the IEEE 802.15.4 standard for WSN. ZigBee devices can be interfaced to the computer or other end points [8]. We need a ZigBee modem in order to connect to user understandable digital interface, such as the computer. Zigbee Modems connect to the USB port of the computer, and mounts on a COM port (a standard serial port). The ZigBee provisions for devices to communicate with each other using a Mesh, Tree or star topology.

As a result, ZigBee modems can be used to talk to many ZigBee devices and we can choose which device we want to talk to at any time. There are two ZigBee modules, series 1 and series 2. A ZigBee Series 2 Modem is needed to talk to ZigBee Series 2 devices. ZigBee Series 2 offers a new feature called mesh networking. Mesh networking allows our computer to talk to devices that are out of range by talking to devices that are in between [9].

C. Rationale to choose ZigBee as preferred communication backbone for emergency response

One of the main design goals of our emergency response system is to have a cost effective WSN. Currently blue tooth offers short personal area coverage however it does not offer the Mesh or Tree networking of ZigBee. Bluetooth is also an IEEE 802.15 WPAN standard and also uses the 2.4-GHz unlicensed frequency band. Like ZigBee Bluetooth also uses small form factors and low power. Some technical differences between Bluetooth and ZigBee can be found in [10].

IEEE 802.11 standard specification provides MAC and PHY layers which can also be used for effective indoor communication over several hundred meters. Here we compare IEEE 802.11, 802.15.4 wireless standards with an emphasis on the physical layer [10]. Interfacing of 802.15.4 to 802.11 devices can be found in [11].

VII. OTHER WIRELESS STANDARDS

The standards given below are version of 802.11 and 802.15 which apply to lo-latency WSNs only, a compressive study is found in [10].

D. IEEE 802.11 - WLAN/Wi-Fi

Wireless LAN (WLAN, also known as Wi-Fi) is a set of low tier, terrestrial, network technologies for data communication. The WLAN standard's operates on the 2.4 GHz and 5 GHz Industrial, Science and Medical (ISM) frequency bands. It is specified by the IEEE 802.11 standard and it comes in many different variations like IEEE 802.11a/b/g/n. The application of

WLAN has been most visible in the consumer market where most portable computers support at least one of the variations.

VIII. NETWORK STRUCTURE FOR WSN

Wireless networks can have two distinct modes of operation: Ad hoc and infrastructure. Infrastructure wireless networks usually have a base station which acts as a central coordinating node. The base station is usually AC provided in order to enable access to the Internet, an intranet or other wireless networks. Base stations are normally fixed in location. The disadvantage over ad hoc networks is that the base station is a central point of failure. If it stops working none of the wireless terminals can communicate with each other [10].

[12] Suggests a protocol for providing a WSN with a hierarchical organization. Differently from previously proposed solutions, the protocol, termed clique clustering (CC), includes in its operation a fail-safe mechanism for dealing with node failure or removal, which are typical of WSN, [3]. More specifically, the network is partitioned into clusters that are cliques i.e., nodes in each cluster are directly connected to each other. An efficient mechanism for building a connected backbone among the clique clusters is provided. Clustering, backbone formation and backbone maintenance are completely localized, in the precise sense that only nodes physically close to a failing node are involved in the reconfiguration process. For more details on the protocol refer [12].

Both the standards described earlier differ by the frequencies they use and this affects the data rate and range they can cover. The given table shows the comparison of the frequency data rate and the range of the standard [10]. We use 802.15.4 due to its low power requirements.

Table 1: Frequencies of operation for 802.11 and 802.15.

Standard Type	Frequency	Data rate	Range
802.11a LAN	5 GHz	54 Mbps	120m
802.11b LAN	2.4 GHz	11 Mbps	140m
802.11g LAN	2.4 GHz	54 Mbps	140m
802.11n LAN	2.4/5 GHz	248 Mbps	250m
802.15.4 PAN	0.868/0.915/2.4 GHz	240 kbps	75m

One of our main design goals is to be able to interface Zigbee devices to a PC. ZUXPProXR Zigbee Interface Module allows for this to happen. Zigbee Interface Module with XR Allows us to Add more relays to this Device and UXP allows us to Add I/O Expansion Modules to the Device expansion ports.

This Device Acts like it is Directly Connected to the Serial Port of a PC. This ProXR series controller offers wireless serial communications, requiring only a 12VDC Power Supply.

Once powered up, the relay controller waits for a command.

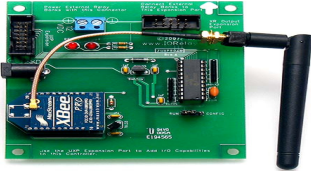


Fig. 2. ZUXPProXR Zigbee Interface Module.

IX. SENSORS

A sensor node is also typically known as a 'mote' a term which is chiefly used in North America. A sensor node in a wireless sensor network is capable of gathering sensory information, processing and communicating with other connected nodes in the network. The typical architecture of the sensor node is shown in Figure 3.

The microcontroller in the sensor performs tasks such as data processing and controls the functionality of other components in the sensor node. Microcontrollers are most suitable for sensor nodes.

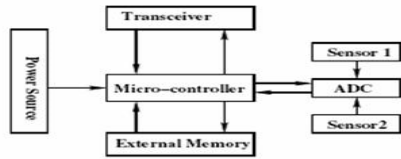


Fig. 3. Sensor Node Architecture.

Most of the sensor nodes make use of the ISM band which gives free radio, a huge spectrum allocation and global availability. The Radio Frequency (RF) based communication is the most relevant form of communication that fits to most of the WSN applications. The WSN use the communication frequencies between about 433 MHz and 2.4 GHz, Table 1. Transceivers lack a unique identifier. The operational states are Transmit, Receive, Idle and Sleep.

From an energy perspective, the most relevant kinds of memory are on-chip memory of a microcontroller and FLASH memory - off-chip RAM is rarely if ever used.

Flash memories are used due to its cost and storage capacity.

The power is stored either in Batteries or Capacitors. Batteries are the main source of power supply for sensor nodes. They are also classified according to electrochemical material used for electrode such as NiCd (nickel-cadmium), NiZn (nickel-zinc), Nimh (nickel metal hydride), and Lithium-Ion. It is also possible to power sensor using alternatives energies such as solar power, wind and many others as research in those areas are making breakthroughs.

A. Temperature Sensing

We use temperature sensing as a case study to show the validity of WSN in the field of emergency responses. A temperature sensor produces a voltage that is proportional to the temperature of the die in the device. This voltage is supplied as one of the single-ended inputs to the Analog to Digital Converter (ADC) multiplexer. When the temperature sensor is selected as the ADC input source and the ADC initiates a conversion, the resulting ADC output code can be converted into a temperature in degrees. The increase of temperature in the room due to fire will increase the voltage of the sensor in this case the die in the device.

In order to find the ambient temperature, the temperature increase due to self-heating must be subtracted from the result. The chief factors that contribute to the amount of device self-heating are: power supply voltage, operating frequency, the thermal dissipation characteristics of the package, device mounting on the PCB, and airflow over the package [13]. The temperature increase can be calculated to the first order by multiplying the device's power dissipation by the thermal dissipation constant of the package. One method is to initiate a conversion soon after applying power to the device to get a 'cold' temperature reading, and then measure again after about a minute of operation, to get a 'hot' temperature reading [13]. The difference between the two measurements is the contribution due to self-heating [13].

B. Equation to calculate the temperature:

The temperature sensor produces a voltage output which is proportional to the absolute temperature of the die in the device. The relationship between this voltage and the temperature in degrees C is shown in Equation 1 [13].

$$V_{temp} = \left(2.86 \frac{mV}{C} \right) \times Temp + 76mV$$

(1)

V_{temp} = the output voltage of the temp sensor in mV

Temp = the die temperature in degrees C

The temperature sensor voltage is not directly measurable outside the device. Instead, it is presented as one of the inputs of the ADC multiplexer, allowing the ADC to measure the voltage and produce an output code which is proportional to it [13].

The code produced by the ADC in left-justified single-ended mode is proportional to the input voltage as

$$\text{follows: } \text{CODE} = \text{Vin} \times \frac{\text{Gain}}{\text{VREF}} \times 2^{16} \quad (2)$$

CODE = the left-justified ADC output code

Gain = the gain of the ADC's PGA

VREF = the value of the voltage reference, which is around 2.43 V if the internal VREF is used.

Substituting Equation 1 into Equation 2, assuming Gain=2 and VREF = 2.43V, solving for Temp and rearranging, we obtain an output Temperature which in terms of CODE and a pair of constants.

$$\text{Temp} = \frac{(\text{CODE} - 41857)}{154} \quad (3)$$

Temp = the temperature in degrees C

CODE = the left-justified ADC output code.

C. Sensor Unit

The project will be utilizing Zigbee and temperature sensor (LM35C). The sensor has a temperature range between -40°C to +110°C with an accuracy -10° across full range.

XI. APPLICATION OF THE EMERGENCY RESPONSE SYSTEM

A. Autonomous early detection

Autonomous early detection of an emergency is a primary way of minimizing damages or life threatening events on campus. We model the emergency detection problem as a node k-coverage problem ($k \geq 1$) in wireless sensor network [4].

Constant-factor centralized algorithms are used to solve the node K problem.

B. Self Powered/ Renewable Energy System

With current advancements in alternative energy the sensors used in the system can be solar powered. Such systems can benefit outdoor sensing and indoors where there are huge skylights or open areas with access to sunlight.

Power consumption is a problem currently being addressed in WSN. Solar powered sensors can provide value to WSN for emergency response by prolonging the life-times of the sensing nodes. Experimental results have proved that certain prototypes like the MPWiNodeX, can manage simultaneously energy from Solar, wind and for charging a NiMH battery pack,

resulting in an almost perpetual operation of the evaluated ZigBee network router. In addition to this, the energy scavenging techniques double up as sensors, yielding data on the amount of solar radiation, water flow and wind speed, a capability that avoids the use of specific sensors.

C. Digital Image Threat Verification System

WSN can be attached with a camera as a sensor instead of a temperature sensor, to record a certain area in the building. This systems can be then use as a surveillance network. Existing research discusses optimizing image segmentation algorithms based on image properties without manual intervention [14]. These methodologies compute image properties such as average edge gradient strength, inter- vs. intra-cluster distances using image color features, and color purity of resultant regions, to train a neural network that maps these to ground-truth labeling on the acceptability whether it is good or bad of the solution in the resultant segmentation [14]. There are methodologies that perform extremely well by correctly predicting the optimal parameters of image segmentation algorithms used [14].

Improvement of data quality: Images viewed by human operators can be enhanced by the computer so that contraband appears in stark contrast to its surroundings so that humans can easily detect it [14].

Automated detection of dangerous explosives: The methodology will depend on the modality of gathering data. In the case of images, the system will have to automatically process such data to enhance its quality, segment objects of interest and then use some features to characterize the resulting regions [14]. However, if the data for analysis is a one-dimensional signal or spectra, the task involves template matching where test spectra are matched with known templates [14]. The data could be simply a measurement or a point in n-dimensional feature space that needs to be classified using pattern recognition techniques.

XII. COMPARISON WITH OTHER SYSTEMS

There is currently no emergency notification which is specially developed for campus emergencies. However the technology has been used in other types of emergency situations such as forest fire detection, navigation during emergency situations, wireless internet information system for medical response in disasters and many more.

XIII. DISADVANTAGES AND IMPLEMENTATION ISSUES

The disadvantages of the system will be inherited from the IEEE 802.15.4 standard and Zigbee.

Another problem in response to emergency situation which hugely depend on the validity of the threat or situation of a real emergency in which emergency service can cut cost by not responding to false emergencies and their time can be better utilized to fight or manage real emergencies.

XIV. CONCLUSION

It is feasible to construct a WSN for emergency response notification using IEEE 802.15.4 and Zigbee. Moreover there is a range of sensing applications which can be developed using 802.15.4 MAC and PHY along with ZigBee stack. This system has the potential to reduce the response time in a cost-effective way. The system is robust and efficient methods can be incorporated to validate the threat by adding some additional options to the sensors, such as image processing and multiple sensors. This can help reduce false positives.

This system will be focusing on one aspect of the emergency detection which is fire which occurs mostly in many campuses across the states. The system can be further developed to detect other emergencies such as gas leaks, gunman on campus and severe weather changes.

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