

## Gas Management & Disaster System Using ZigBee

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### Abstract

*Gas leakage is an important problem. It wastes energy and sometimes it causes harmful effects to lives. We have limited energy resources. Proper utilization of resources is need of the time. We have proposed a gas safety management system using ZigBee to monitor flow and pressure of gas, earthquake, temperature, smoke and leak of methane. It also provides a health safety system simultaneously by automating the associated devices with its embedded programmed feature to procure the environment by completely eradicating the harmful source. Through this dynamic technology, we can establish a well economic and health caring system in this rapidly developing era to excel our country.*

Keyword: ZigBee Networks, Gas Management System (GMS), Full Function Device (FFD), Reduced Function Device (RFD), TIN (total input), TOUT (total output)

### 1. Introduction

Wireless sensor network is an interesting research topic. Release of standards like IEEE 802.15.4 and ZigBee in the field have brought the technology in industrial domain [11]. This advancement has led the world toward evolution of many commercial products [5] like home automation and remote monitoring. Previously proprietary routing algorithms and RF technology were used in sensor networks, but now standards-based networking and RF solutions are used in products. Based on the Open System Interconnection model, the Physical and MAC layer standard, defined that it would have a data rate of 250 kb/s with the radio having direct sequence spread spectrum as modulation technique, it operates in the 2.4 GHz the unlicensed band. It has lower bit-rate alternatives in the 868 MHz and 900 MHz bands [12]. On top of these two standard layers, several proprietary and standards-based sensor network systems emerged. ZigBee standard is the one with most vendor and end-product support. ZigBee joined the well-established Bluetooth and Wi-Fi band of 2.4 GHz. It looks mostly like Bluetooth but it is simpler, has fast connection time, longer battery life and a lower data rate.

Today, high class apartments are equipped with safety devices at facilities of gas, electricity and water. It is clear that a sensor will make our lives safer and more comfortable in the future. We can use it as a fire alarm or a gas leak detector. We propose a gas safety management system using an intelligent ZigBee based system. System includes ZigBee network technology, automatic gas leak cutoff, sensors of smoke, methane, and temperature. At first we deployed the ZigBee coordinator, then we used sensors for

quick monitoring and at last ZigBee controller to take action as needed. Action included wall-pad opening and closing which has a built-in cutoff valve and sensors of flow, pressure, and earthquake. That ZigBee controller operates its inner valve and shut off the gas, serving a warning on users if any unusual is occurred for gas flow, pressure, earthquake, temperature, and leakage of gases in gas pipeline and facilities. Our gas safety management system is configured by the topology of star types with those devices and sensors and then controls all the devices through a wall-pad including a gateway [2] with ZigBee network, and takes safety measures to protect a serious risk. In this paper, the proposed system used ZigBee wireless device, sensors and ZigBee controllers. System will increase performance and will provide safety.

### 2. Comparison between ZigBee and other technique

ZigBee is tremendously better than any other technologies [6] like Bluetooth, Wi-Fi and Home RF because of its supreme performance in any comparison on different technical aspects. Below mentioned is the comparison of ZigBee with other technologies.

	ZigBee	Bluetooth	Wi-Fi	Home RF
<b>Frequency Band</b>	2.4GHz / 915MHz / 865MHz	2.4GHz	2.4GHz	2.4GHz
<b>Maximum bit rate</b>	250kb/s	1 Mb/s	1 Mb/s	1.6Mb/s
<b>Power</b>	Low	Medium	High	Medium
<b>Coverage Area</b>	100 m	10	50	50
<b>Network Nodes</b>	65,000	80	50	127

**Table 1: Comparison between ZigBee, Wi-Fi and Bluetooth**

### 3. ZigBee technical characteristics

ZigBee is a wireless communication technology applied in short range. It has low transmission rate between the various electronic devices. ZigBee is an emerging wireless transmission technology standard. It has its unique technical characteristics. The notable advantage of ZigBee is that it has long battery life; low power consumption; and reliable connections [4]. It uses free frequency range that why it is suitable for home

applications. For commercial purpose it results low cost and reliable networks. When ZigBee node is under workingmode, the transmission rate is low, the amount of data transmission is small, all these factors reduce the time of receiving and sending signals and when it is under nonworkingmode, ZigBee node is dormant. Both of two working modes determine the low consumption.

ZigBee is a kind of wireless communication technology. It is applied in short range, low transmission rate between the various electronic equipments. ZigBee as emerging wireless transmission technology standard has its unique technical characteristics:

#### A. Reliability

ZigBee MAC layer [9] adopts talkwhenready collision avoidance mechanism. Under this mechanism, when the data transmission requirements appeared node will send each packet immediately and wait for confirmation reply information comes from the recipient. We fit does not receive any confirmation then the end devices directly communicate with the ZigBee coordinator. ZigBee coordinator is responsible for forming the network in mesh and tree topologies [1] and for choosing certain key network parameters but by the use of ZigBee routers the network can be extended. In our system we are using star topology. In star topology, a central unit is controlling all network devices.

#### B. Low Power Consumption

ZigBee uses low power [9]. Battery timing may be extended from half to full year. This feature of ZigBee makes it reliable and suitable in all environments.

#### C. High Expansibility

A ZigBee network can contain 255 ZigBee nodes, one is the master node and others are all slave nodes. Ifrough network coordinator forms net, and network coordinator can also interconnected each other, the whole net can contain 65000 nodes. At last the whole number is very considerable.

### 4. How ZigBee network works

There are two types of devices in a ZigBee network [12], one is the full function device (FFD), and the other is the reduced function device (RFD). In the network, FFD can be the network coordinator or the router, and also can be the terminal device linking to the network. While the RFD cannot be the coordinator, it only can connect to FFD as a terminal device. ZigBee networks use Controller, router (optional) and end devices to communicate. Network devices based upon ZigBee technology like coordinators and end devices gets together to form a ZigBee wireless network. Networking coordinator works as a primary device in ZigBee based system. It is an origin to commence a networking process. It sends information to end devices. The end devices are secondary medium which coordinate with ZigBee controller. An important point is that the end device only works as a receiver within essential time span less than 15msec.

### A. ZigBee Stake

Based on the physical and MAC layers specified by IEEE 802.15.4 WPAN standard, the ZigBee specification establishes the framework for the Network and Application layers. The protocol stack of ZigBee networks is detailed in fig 1.

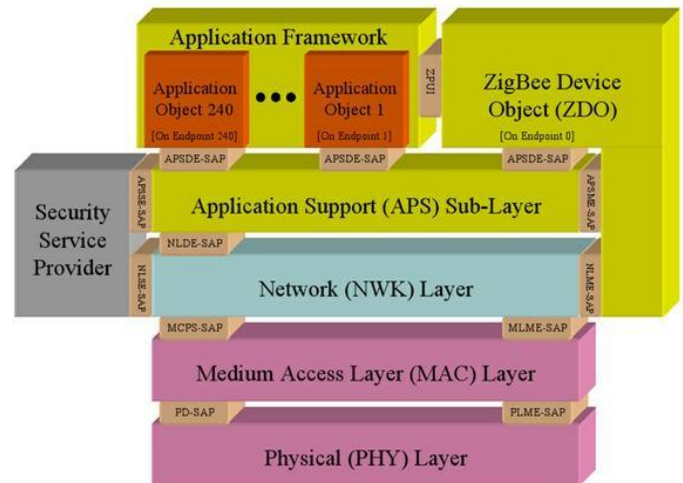


Figure 1: ZigBee Stake

Two device types are specified within the IEEE 802.15.4 framework. First is full function device and reduced function device. An FFD has more responsibilities in that they must maintain routing tables, participate in route discovery and repair beaconing framework. It handles node joins. Moreover, an FFD has the capability of communicating with any other devices within its routing, the end devices have to rely exclusively on their parent nodes to perform mesh routing on their behalves.

#### B. General Parameters

<b>Network Size</b>	45m x 45m
<b>Number of Nodes</b>	18 nodes
<b>Transmission Range</b>	10 meters
<b>Network Setup Time</b>	30 seconds
<b>Number of Concurrent Data Flows</b>	3

Table 2: General parameters

### 5. ZigBee network topologies

ZigBee networks use different network topologies like peer-to-peer, star topologies and mesh [12].

#### A. Peer to Peer Topology

In peer-to-peer topology ZigBee network nodes help other devices to directly connect to each other [8]. One node of ZigBee network device keeps the ability to form a network by connecting multiple devices. In peer-to-peer networking topology one ZigBee network device node is connected with the other node for network formation. It forms a grid like

structure. ZigBee networks have short range wireless networking. ZigBee networks relatively form a simpler network, they don't have any complexity.

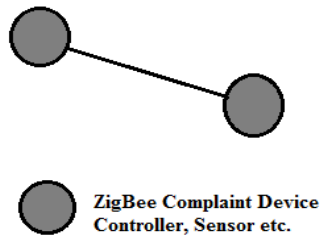


Figure 2: Peer to Peer Topology

### B. Star Topology

Star topology of ZigBee [2] network makes all the devices attached to a central control unit. Multiple routers may also be used to increase ZigBee network range. The complexity of this module makes it difficult to tell that which node is connected to which one but in case of any breakdown the ZigBee network finds an alternate route to execute the command sending through coordinator and does not get affected itself.

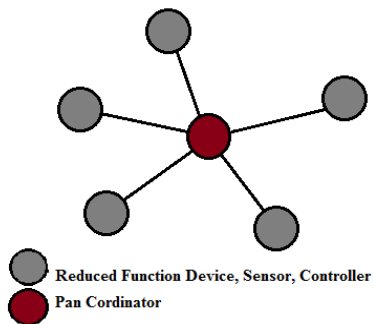


Figure 3: Star Topology

### C. Mesh Topology

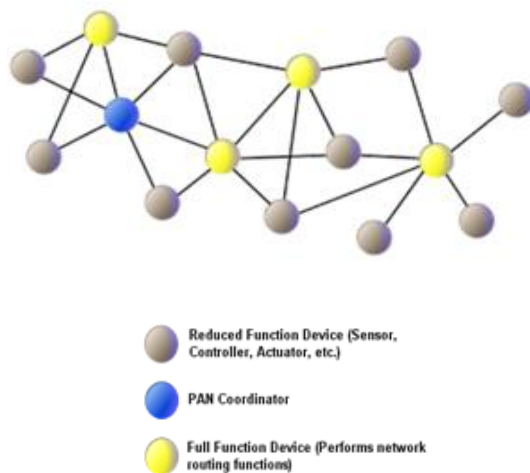


Figure 4: Mesh Topology

## 6. ZigBee network devices

### A. Coordinator

There are 14 channels in the default scan channels list (11 – 24), coordinator is configured to start a network on one of these. The coordinator performs an energy scan and active scan to ensure it selects a channel with minimal energy where a PAN ID conflict will not occur. The coordinator, by default selects a random 16-bit PAN ID for the network. The coordinator is also configured as the trust center and network manager.

### B. Router

The router is configured to make three attempts to join a network when first powered on. By default, the router will scan 14 of the 16 channels (11 – 24) and join any PAN that is allowing joining. After the router joins a network, it will attempt to discover an endpoint on the trust center that supports key establishment by sending a match descriptor request to the coordinator. If the trust center responds with a match descriptor response, the router will attempt to perform key establishment.

### C. End Device

The end device is configured to make three attempts to join a network when first powered on. By default, the end device will scan 14 of the 16 channels (11 – 24) and join any PAN that is allowing joining. After the end device joins a network, it will attempt to discover an endpoint on the trust center that supports key establishment by sending a match descriptor request to the coordinator. If the trust center responds with a match descriptor response, the end device will attempt to perform key establishment.

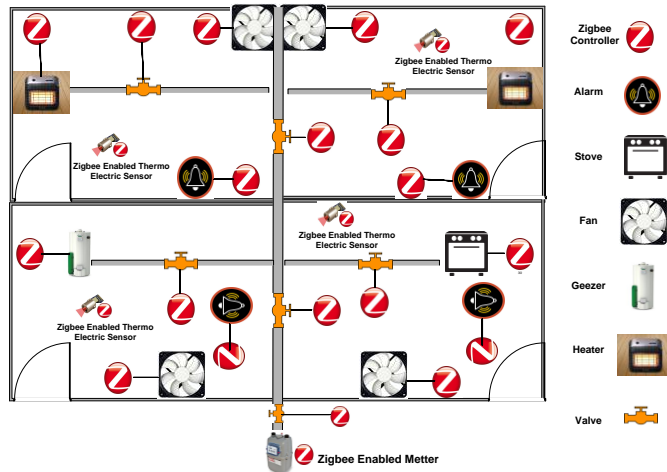
When the end device joins a network it will send a modem status API frame out its UART indicating the end device has joined a network. Then it will send an API frame out the UART [8] indicating the device authenticated successfully, and its Associate LED pin (pin 15) toggles at a rate of two blinks per second. The AI command, if queried returns a value of 0, indicating a successful join to a smart energy network. Once the end device has joined a network, it sends a poll request to its parent device to see if the parent received any RF data in its behalf. The end device continues polling while awake, disabling its receiver between polls if the parent has no data for it.

## 7. How ZigBee GMS works

The system is based on gas leakage prevention and health care system through ZigBee Technology. We have installed ZigBee device (RFD) in every room of the house [11]. Whereas these rooms are having Heater, Geezer and Stove like appliances in them.

ZigBee device controllers and sensors are programmed to inform ZigBee coordinator (FFD) [3], in case if Co or Co2 increases in the room more than the set level. In response ZigBee coordinator will address to the ZigBee controller to turn off the appliance immediately.

This system is also capacitated to prevent the gas leakage. For instance this house is provided with the total gas pressure of 4 Cubic Hector. ZigBee coordinator detects [10] that provided gas pressure is decreasing to 3 cubic Hector then it will start checking every room for gas leakage with the help of ZigBee devices and Sensors [3].



**Figure 5: Block Diagram for Gas Management & Disaster system**

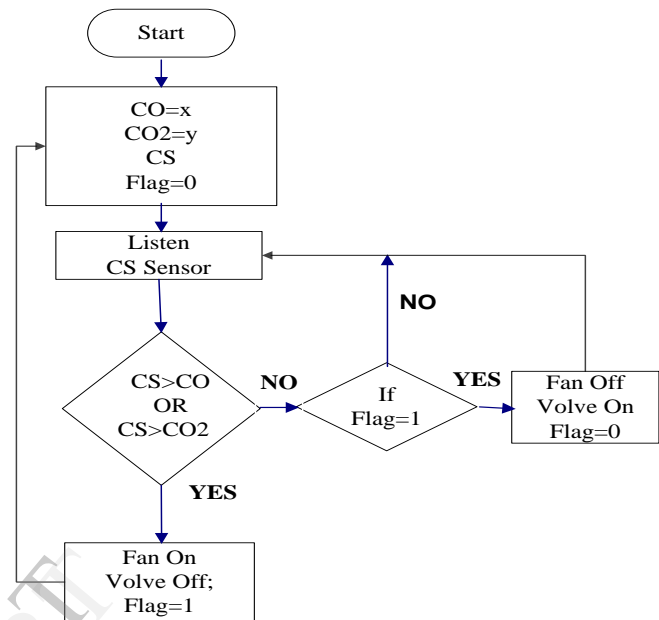
It will perform thorough check to 1st, 2nd, 3rd and 4th room respectively. Let's see how it will enquire for the gas leakage detection. First of all it will check the first room by turning off the gas connectivity and see if the main pressure retains to 4 Cubic Hector, In case of negative detection to room 1, gas supply will again continue to that room. For instance gas leakage is found in room 3 then gas provision to room 3 will be discontinued and rest of the rooms will be carried on with the gas supply. Similar step will be done to check for the leakage until the detection is succeeded in every room. In Case if no gas leakage is found in any room then it will presume that leakage is on the main gas supply line and will turn off the safety valve of the main line.

Whereas ZigBee room sensors are programmed to raise alarm [8], on sensing the methane gas release in the air, by reporting to ZigBee coordinator to turn off the particular room gas valve. This system is also very effective for health care system. For example in case of gas load shedding, some food was cooking on the stove and gas was turned off and comes again then the discharged methane gas in the room will be sensed and reported to the ZigBee coordinator to turn off the supply of the particular room. ZigBee Coordinator is intelligent [7] enough to control the devices and sensors itself independently.

#### A. Environment Control System

Environment Control System is designed to check the quantity of Carbon dioxide and carbon mono oxide in the room. If the quantity of carbon dioxide and carbon mono oxide will be more than desired requirement than system will start exhaust

fan and start alarm to intimate home members. This system will save lives in two ways. First, it will start exhaust fan and close the valve to decrease the quantity of these gases in the room. On the other hand it will start alarm to make household members attentive.



**Figure6: Environment Control System**

Above figure shows all flows in system. It implements the core idea and as a result it will work as per system requirements.

#### B. Heat Control System

This system is design with RFD device [12]. This system will find temperature value with RFD device. As the value of temperature increased the carbon dioxide, sensors will detect this change in room temperature automatically. After detecting temperature the sensors will send instructions to ZigBee coordinator. Thus, the sensor has two jobs: detection of heat; sending instructions to ZigBee coordinator. After receiving instructions from sensors the ZigBee coordinator will give instructions to ZigBee controller. Its job of ZigBee controller to take necessary action as required. ZigBeecontroller resolves this issue by closing the valve connected with heater and turn on the exhaust fan. It will be an effective solution because excess heat and carbon dioxide will be exhausted from room and new heat generation will be closed when heater will be turned off. System has two major functions. It will close the valve and start the fan to manage the temperature. This system is designed feedback mechanism. The system will find specific value until the temperature is balanced. ZigBee controller and temperature sensor are used in this system. When temperature in room will be normal the controller will turn off the fan and start the heater again. Whole process will be completed in good way.

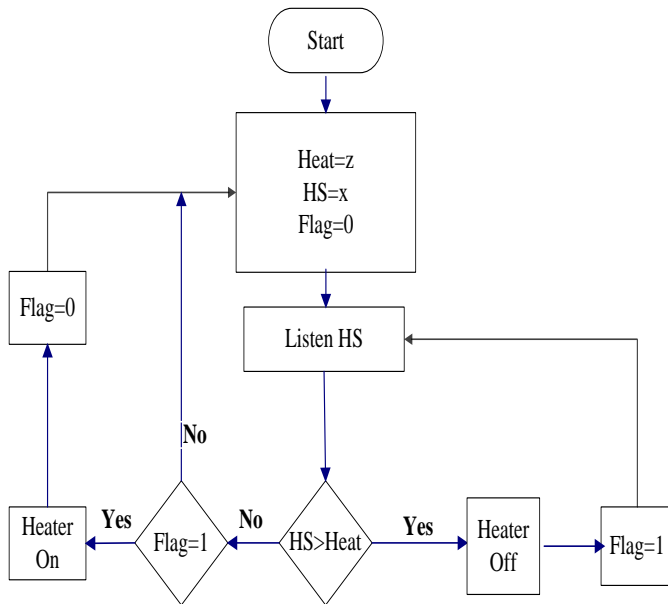


Figure7: Temperature controlling feedback system.

### C. Gas Leak Detection System

This system is solution for detection of gas leakage. System achieve this task by comparing input of gas and usage in apartment. System coordinator which will function with gas meter will calculate exact incoming gas. When home accessories like heater, stove will utilize the gas the ZigBee coordinator will calculate it again. For instance this house is provided with the total gas pressure of 6 Cubic Hecter. ZigBee coordinator detects that provided gas pressure is decreasing to 4 cubic Hecter then it will start checking every room for gas leakage with the help of ZigBee devices and Sensors.

System will perform this action by checking from 1<sup>st</sup> to 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> room one by one. First, it will check the first room by turning off the gas connectivity and see if the main pressure retains to 4 Cubic Hecter, In case of negative detection to room 1, gas supply will again continue to that room. For instance gas leakage is found in room 3 then gas provision to room 3 will be discontinued and rest of the rooms will be carried on with the gas supply. Similar step will be done to check for the leakage until the detection is succeeded in every room. In Case if no gas leakage is found in any room then it will presume that leakage is on the main gas supply line and will turn off the safety valve of the main line.

The following process flow diagram shows that two main variables; TIN and TOUT will perform this task logically. After initialization of the system, input variable TIN will calculate total incoming gas. It will constantly compare this value with TOUT. TOUT value will be calculated with the help of sensors and ZigBee devices.

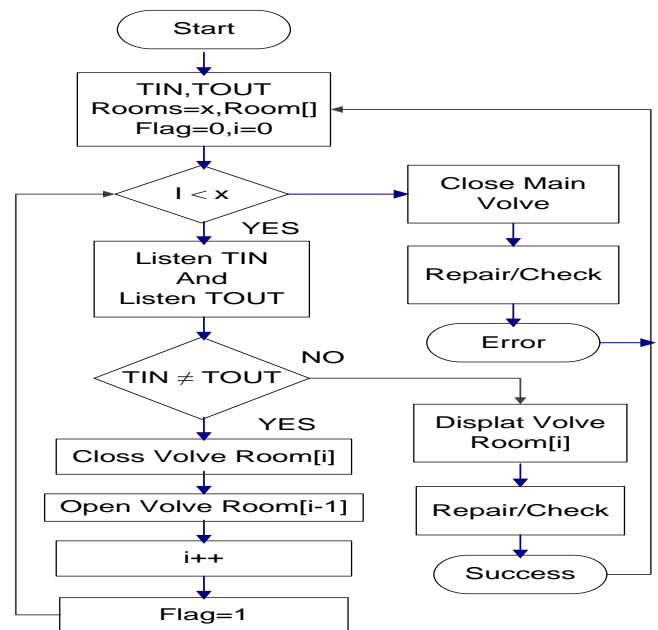


Figure8: Gas Leak Detection System

## 8. Conclusion

As our country is under great economical crisis and our present natural resources are needed to be utilized with intense care. Therefore, our research paper is very helpful solution to overcome our presently confronted economical issues and as well as for our wasted energy resources. Normally in every region, whether it is industrial area or residential area, gas leakage is very common. In our research paper, we have presented a dynamic and intelligent system which is based on ZigBee Technology; through this we can prevent gas leakage which will save our energy resources from wastage. In future, these systems can be implemented in industrial sector. This thing will minimize production cost by utilizing energy resources in more efficient way.

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