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Resource Efficient Wireless Sensor Networks for Temperature and Gas Monitoring

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Abstract

Health and safety plays an important role in everyday life. Inhaling poisonous gas may lead to harmful effect; hence monitoring the air quality is essential. Wireless Sensor node can monitor temperature and air quality, which helps us to avoid the disaster. The main problem with Wireless Sensor node is that it consumes more energy for monitoring the environment. Existing system reduces the power consumption by making the node to switch between sleep and wake state. During the sleep state, the power consumption of the sensor is negligible and the power consumed by the sensor node is reduced. Existing system does not consider the occurrence of collision of the signals during transmission. A hybrid technique is proposed based on the priority, aggregation and scheduling of data to avoid the collision of signals during transmission. This reduces the energy consumption of the Wireless Sensor nodes by accumulating the high priority signals together and transmits without collision. The proposed work is used to monitor the air quality and temperature with reduced power consumption. An alert message is also generated and transmitted to the user in case of emergency.

Keywords – Aggregation, Power consumption, Priority, Scheduling, Wireless Sensor Node.

1.INTRODUCTION

Health and safety is very essential in the fast progressing world. In general, we do not spend much time in taking care of our health unless a serious problem occurs. In such places sensors are very helpful in indicating the safety environment for human being.

The wireless sensor nodes are used in places where the human intervention is not present. Its main application is in military field to monitor the movements of enemy.

Each sensor node has several parts: a radio transceiver with an internal or external antenna to send and receive signal, a microcontroller and an electronic circuit to connect the sensors and an energy source. The energy source will usually be a battery or an embedded form of energy harvesting. A sensor node might vary in size based on the area it is used. The dimension and cost constraints on sensor nodes result in parallel restriction on resources such as memory, communication bandwidth, energy and computational speed.

This paper focuses on the energy reduction and communication bandwidth, main resources for reducing the cost of sensor node. The life time of the sensor node is increased if the energy consumed by the node is decreased. In this paper the sensor node, includes a temperature sensor, a gas sensor and a ZigBee transceiver.

ZigBee has astonishing characteristics like least data rates, extended life for battery, and safe networking. ZigBee has a definite rate of 250kbit/s, which is best suited for single signal transmission from a sensor. Although low-powered, ZigBee devices can broadcast data over long region by passing data through intermediate devices to reach more distant ones thereby creating a mesh network.

The gas sensor is used to monitor the air quality of the environment. Here, we use MQ135 for monitoring the air quality. It uses SnO_2 for sensing. The sensor's conductivity is higher along with the rise in gas concentration. MQ135 gas sensor has superior sensitivity to Ammonia, Sulphide and Benzene steam, and also susceptible to fume and harmful gases. It is of low cost and has long life.

The temperature sensor monitors the variations in the temperature in the environment. The LM35's is used here as the temperature sensor which has tiny output impedance, linear yield, and specific inherent calibration which make the interfacing to control circuitry easier. It can be operated with single power supply, or with positive and negative supplies. As it consumes only 60 µA from the supply, it has extremely less self-heating, which is less than 0.1°C in still air. The LM35 is evaluated to operate over a −55° to +150°C temperature range. It is of low cost as it involves wafer-level trimming.

The sensors and ZigBee are embedded to the microcontroller unit. The controller unit analyses the values received from the sensors. If the values are above the normal temperature or concentration of gas then the signal is prepared and assigned a high priority to it. The controller unit generates a signal along with priority and sends this signal to the neighbor node using the ZigBee. The neighbor node then aggregates this signal with its own signal and forwards. The main sensor node then forwards this abnormality in the environment to the human through the communication number.

Our approach mainly concentrates to

- Monitor the temperature and air quality in the environment.
- Reduce power consumption.
- Alert people in case of emergency.

The remainder of the paper is organized as follows. Section II deals the related work for the gas and energy efficiency. Section III includes the network architecture of the proposed work. Section IV narrates the algorithm to conserve the energy. The benefits of the proposed work is explained in Section V. Conclusion of the work is presented in Section VI.

1.1 RELATED WORKS

A multi disciplinary approach is essential to develop an energy-efficient technique for battery-powered applications,. In [2], two kinds of Wi-Fi architecture (infrastructure based and access point based) are used. Based on the room location and architecture, wired and wireless sensor nodes are used. The optimal value for the temperature and humidity is provided by neural network (which gets the temperature and the humidity values from the respective sensors). The shortcoming of this paper is that, it requires 8V to operate, which therefore directly affects the lifetime of the sensor node. These nodes can operate for only days, or hardly a month. In addition to that, the gas concentration is considered by sensors for monitoring the temperature and humidity, which cross influences the original value. There are several examples in literature of sensor systems for monitoring IAQ.

In [3], a computerized decentralized indoor climate control system is presented, including motionless wired multi-gas sensor modules and wearable wireless devices. Energy utilization of the system is not mentioned. Postolache et al. [5] present a WiFi network for indoor and outdoor air quality monitoring with MOX sensor arrays from Figaro [4]. They are focused on superior onboard processing and data publishing on the Web. Power consumption of the nodes is very high (8 W). In [1], the temperature issue is resolved, but the power consumption is high as it follows star topology to send signal.

Choi et al. [6] and Rossi [7] present design and implementation of sensor systems for air contamination monitoring with IEEE 802.15.4/ZigBee communication protocol. Both build up various types of gas sensors on their boards, developed an programmed sensor-specific power management system and used pulse mode of the gas sensors, but the typical current consumption of their solutions is still quite high (about 100 mA).

Gupta et al. [8] propose an adaptive sampling algorithm for wireless air contamination sensor network, but the algorithm was not implemented in the node.

We focus on developing an energy efficient algorithm which reduces the power consumption drastically and thereby naturally increases the life of the sensor node.

2. NETWORK ARCHITECTURE

The proposed network consists of number of sensor nodes within the closed environment. Each sensor node consists of a temperature sensor, gas sensor, ZigBee and a power circuit. The main sensor node alone consists of GSM along with ZigBee to send an alert message to the communication number. The overall architecture is specified in fig.1.

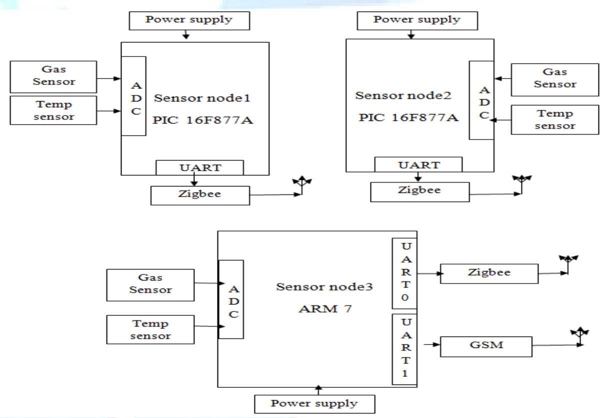
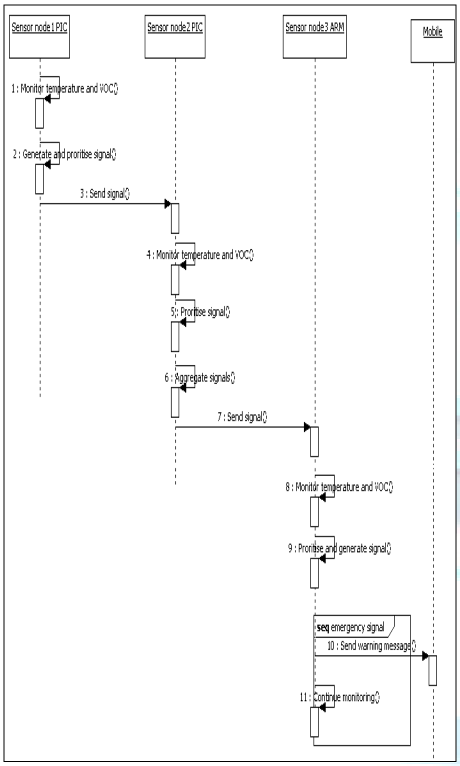


Fig. 1. Network architecture with all components

A.PIC16F877A Microcontroller unit

PIC16F877A features 256 bytes of Electrically Erasable Programmable ROM data memory, automatic programming, an ICD, 5 channels Analog-to-Digital converter, 2 timers, 2 confine/ distinguish /PWM functions, the synchronous serial port is configured as Universal Asynchronous Receiver Transmitter (USART).

MQ135 use SnO_2 for sensing. The sensor's conductivity is higher as there is rise in gas concentration. MQ135 gas sensor has superior sensitivity to Ammonia, Sulphide and Benzene steam, and also susceptible to fumes and harmful gases. It is of low cost and has long life.



C.LM35 Temperature sensor

LM35 has tiny output impedance, linear yield, and specific inherent calibration which make the interfacing to control circuitry easy. It can be operated with single power supply, or with positive and negative supplies. As it consumes only 60 µA from the supply, it has extremely less self-heating, which is less than 0.1°C in still air. The LM35 is evaluated to operate over a −55° to +150°C temperature range.

As specified earlier, the microcontroller analyses the values obtained from the gas and temperature sensor. A predefined value for the normal temperature and concentration of various gases are specified. These are called as normal values. Values that are present above this range are called abnormal values. When the microcontroller gets values from temperature and gas sensor, it verifies with the normal values. If not, then the controller generates a signal with high priority, else signal is generated with low priority. The node that has high priority sends the signal first, while the normal priority signals are sent after that.

Our proposed paper works as follows. As shown in fig.2, the sensor node1 generates a signal with the priority and send it to the neighbor node. The neighbor node (sensor node2) aggregates this signal with its original signal and send the new signal to the sensor node3 (main sensor) which has both ZigBee and GSM.

3. PROPOSED WORK

The proposed energy efficiency algorithm is to reduce the energy consumed by the sensor node. We introduce two algorithms here, to reduce the consumption of resources memory, communication bandwidth computational speed and energy,. The algorithm1 is implemented in each sensor node to reduce the consumption of resources and the algorithm2 demonstrates the operation of the sensor network.

Algorithm 1: ENERGY EFFICIENCY ALGORITHM

Begin
1: wake
2: t✱ temperature in room
3: g✱concentration of gases
4: **if** (g>ab1 or t>ab2) **then**
5: s✱Generate signal with priority 1
6: send the signal at time t1
7: **else**
8: s✱generate signal with priority 2
9: send the signal at time t2
10: **end if**
11: sleep for 10sec
End

The variable "t" stores the temperature of the room and the variable "g" stores the concentration of gases in the room. The "ab1" and "ab2" denotes the normal values for temperature and gas respectively.

Algorithm 2: OPERATION OF SENSOR NETWORK

Input: Signal from neighbor node
Output: Message to mobile with aggregated signal
1: Receive the signal
2: Checks is there is any abnormality in the value through the specified priority of signal.
3: If signal is of high priority then message sent by this sensor is also of high priority.
4: Else it checks the value of its own sensing region
5: If abnormality is found then high priority signal is generated.

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6: The signal is sent to main sensor node.

7: An alert message is generated and sent to mobile.

The proposed sensor network will reduce the energy consumption of the sensors by eliminating redundant transmission of signal between the signals transmitted by the sensor nodes.

Let us assume that a frame include both sleep and wake state. So,

$$frame = sleep + wake$$

The energy is consumed by the sensor node only when the system is in wake state.

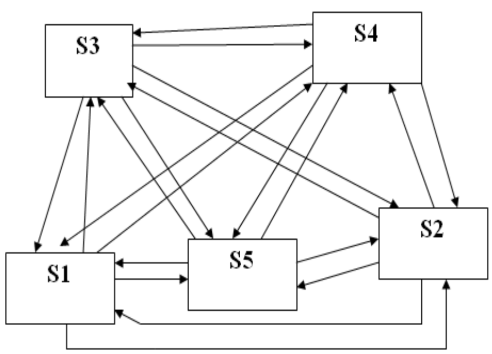
$$Energy\ consumed_i = frame/2$$

In the proposed scenario, the sensor node is in sleep state for 10sec for every 5sec. This implies that the sensor node is wake for 20sec in 60sec (1minute).

$$T_{wake} = 20/60 \text{ per min}$$

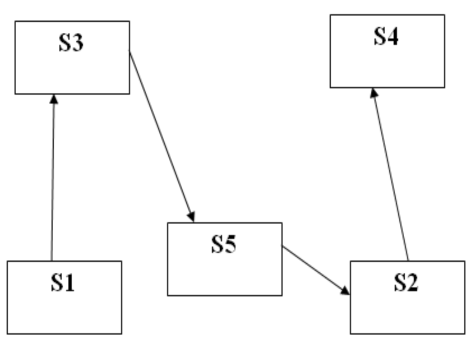
In general, energy consumption for sending signal from one node to another = 1mW

Existing system



Energy consumed=0.33*5*4
= 6.6mW/min

(i) Proposed system



Energy consumed=0.33*4 ***=1.32mW/min***

Result

Figure 3 shows the sensor node which has LCD display to show the abnormality and normality in the region. Figure 3 shows the gas sensor (At Left = first one) and temperature sensor (At Left = second). The ZigBee transceiver (right- at the bottom) is used to send and receive signal.

$$Energy\ consumed_f = (20*1mW)/60 \text{ per min}$$
$$= 0.33mW/min$$

In the present scenario, the signal is sent through mesh network. So, if there are n nodes, then

$$Number\ of\ transmission_{nn} = n * (n-1)$$

Hence for n nodes, the energy consumed is given by,

$$\textbf{Energy consumed}_n \mathbf{= 0.33*n*(n-1)mW/min}$$

But in the proposed network the signal is transmitted only to the specified sensor network. Hence if there are n nodes, then only (n-1) transmission are made.

$$Number\ of\ transmission_{nf} = (n-1)$$

Hence for n nodes, the energy consumed is given by,

$$\textbf{Energy consumed}_{nf} \mathbf{= 0.33*(n-1)mW/min}$$

For ex, if there are 5 nodes in a network, we calculate the energy consumed by system in existing and proposed algorithm.

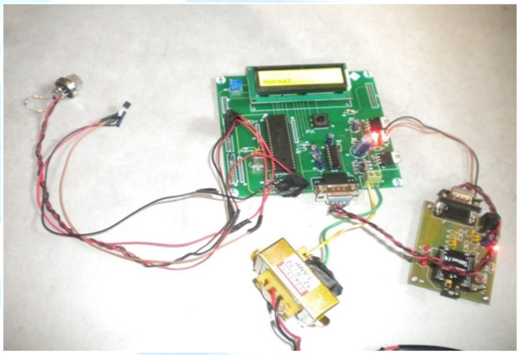


Fig.3. Sensor nodes to measure temperature and gas.

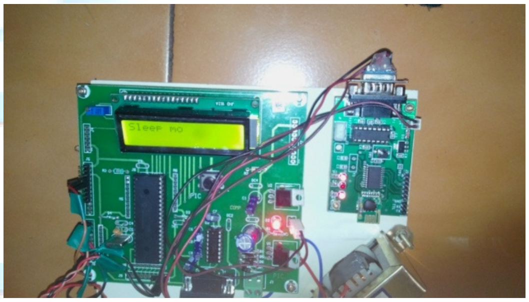


Fig. 4. Sensor node when it is in sleep state

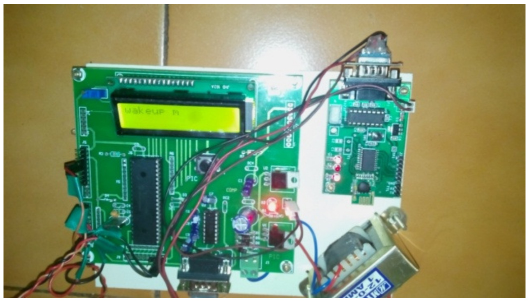


Fig. 5. Sensor node when it is in wake state

Three sensors are developed to measure the power consumption. One sensor node consists of Zigbee and GSM, while the other two sensor node contains only the Zigbee.

Fig. 6. Three nodes in closed environment

In the figure below, Zigbee is present at the left end and GSM is present at the right corner. The ARM controller is present at the centre of the node.

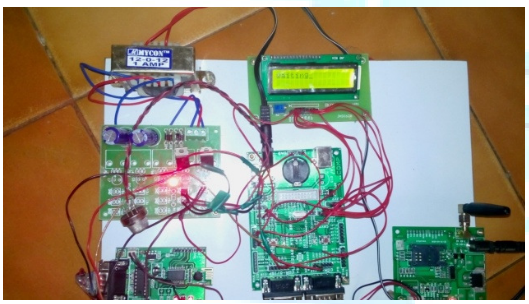


Fig. 7. Sensor node when it is in waiting state

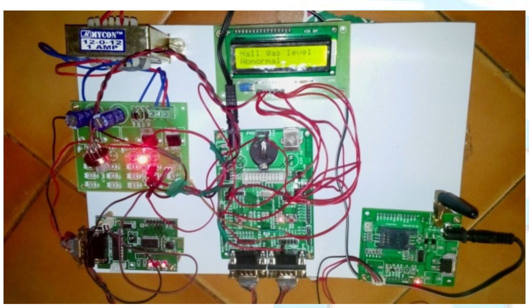


Fig. 8. Sensor node receiving abnormal signal

Fig. 9. Mobile receiving alert message

An alert message is sent to the mobile once the abnormality is found in the observation environment.

Further, the sensor network is also simulated using the simulation tool Proteus 7 Professional. An ISIS environment is created with temperature and humidity sensors. Each sensor has a plus and minus symbol which is used to increase and decrease the values.

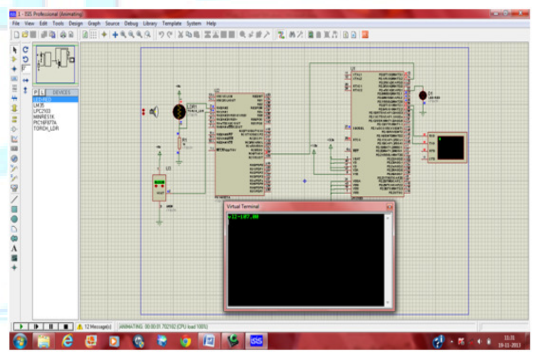


Fig.10. ISIS environment with light and temperature sensors.

The output of the sensor is given to the PIC controller. It verifies the values with the predefined normal values. It then generates and sends the signal to the ARM controller through the transceiver. The ARM controller has both ZigBee transceiver and GSM. The ARM receives the signal through ZigBee transceiver and displays the values through the virtual terminal. The normal value does not have any specific significance, while the abnormal value has to be sent to the mobile through the GSM.

Initially, the values of the sensors are set to normal range. val1 and val2 represent the values of temperature and light sensor respectively.

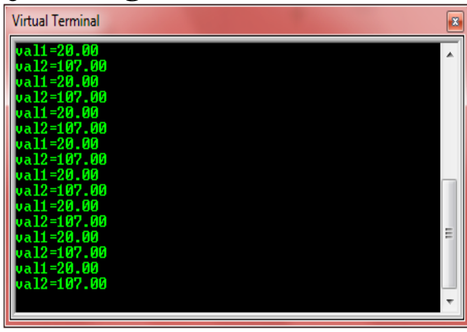


Fig.11. Virtual terminal which displays the light

and temperature value.

The virtual terminal, in fig 11, displays the values of temperature and light sensors. The values of the light and temperature are increased using the plus symbol present near the sensors. The abnormalities are represented as "A" in fig.12 and fig.13.

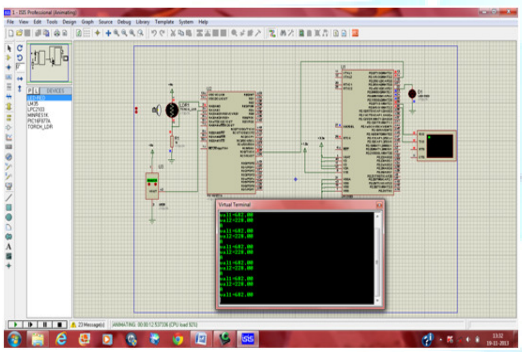


Fig.12. ISIS environment after increasing light and temperature value.

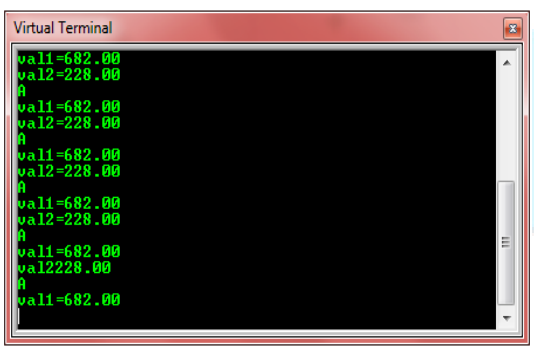


Fig.1 3. Virtual terminal indicating abnormality.

Fro In this simulation we can estimate the power consumed by by sensor after implementing the energy efficient Algorithm.

I. CONCLUSION

A sensor network is developed with temperature and gas sensor in real time to measure the temperature and gas. Further, the Proteus 7 Professional is also used to create an environment of the sensor nodes to measure the temperature and the gas. Two algorithms have been proposed to reduce the resource consumption of the nodes which will increase the life-time of the sensors. The proposed algorithm gives priority to the signals that have abnormal values and avoids collision with low priority signals.

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