Design of Robust Sensor Nodes to Monitor Carbon Monoxide and Natural Gas Levels

Elizabeth Rufus[1]

[1] VIT University

Received: 16 December 2012 Accepted: 1 January 2013 Published: 15 January 2013

Abstract

In the present scenario, effective real time pollution monitoring equipments require large number of nodes (preferably >50) which are capable of interaction and hence provide reliable information. Increasing the number of sensors increases the possibility of determining the exact amount of gas levels in the surrounding environment. Hence the sensor nodes and the wireless network should together work cohesively to determine the correct levels of the gas desired to be monitored. Also it is important that the sensor node has low power consumption and is robust in extreme climatic conditions. Our main focus is to develop many such sensor nodes and develop a simple protocol to effectively use them. In this paper we have only considered the design of one such node which can sense the levels of Carbon Monoxide, and hence a solid-state semiconductor Carbon Monoxide gas sensor is used. The paper describes the parameters like robustness, low power requirements and a highly efficient mode of communication to design a sensor node.

Index terms— microcontroller, gas sensor.

1 Design of Robust Sensor Nodes to Monitor Carbon Monoxide and Natural Gas Levels

Elizabeth Rufus ? , Paritosh Sinha ? , Prabhat Suman ? & Sanket Jaiswal ? Abstract-In the present scenario, effective real time pollution monitoring equipments require large number of nodes (preferably >50) which are capable of interaction and hence provide reliable information. Increasing the number of sensors increases the possibility of determining the exact amount of gas levels in the surrounding environment. Hence the sensor nodes and the wireless network should together work cohesively to determine the correct levels of the gas desired to be monitored. Also it is important that the sensor node has low power consumption and is robust in extreme climatic conditions. Our main focus is to develop many such sensor nodes and develop a simple protocol to effectively use them.

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2 I.

Introduction he impact of pollution on the overall quality of life has been massive. Be it social or scientific, pollution has adversely affected all hemispheres of one's life. The influence of Carbon Monoxide in such circumstances cannot be ignored. The impact has been felt greatly in the developing countries where the technological advancements are leading to increasing amount of Carbon Monoxide levels. To measure the levels, these countries require not only accurate but inexpensive methods of gas detection. The proposed wireless sensor network will satisfy these requirements and provide a satisfactory solution.

Plentiful of research works have been published on the ways to develop and design sensor nodes to detect and monitor Carbon Monoxide levels in the environment. For example, [1] describes development of sensor nodes with precise calibration techniques used for accurate determination of various gas levels in the atmosphere. Although the technique used is effective for near accurate measurements, the design is not robust as the reliability of sensors is not guaranteed in harsh conditions.

Another design as described in [2] involves using a PIC microcontroller and a self-devised protocol to establish a connection between the sensor node and a central computer system. The sensor node in the specified work contains a temperature sensor, resistive type humidity sensor, light to frequency converter, air contaminants sensor, natural Gas (methane) sensor and a Carbon Monoxide sensor. The design is tested in critical climatic conditions and found to perform with the same reliability and accuracy. But the above proposed design does not have the capability to handle a large number of nodes. For the specific task in hand, our setup requires communication among at least 50 nodes. More number of nodes will increase the possibility of accurate measurement of CO levels as sensor measurements are specific to concentration levels of CO in the vicinity of the node. To enable effective communication among a large number of sensor nodes, SimpliciTI protocol is used. SimpliciTI enable wireless communication among a maximum of 100 nodes, which is apt for our project requirements. Moreover as discussed in [1], large number of sensor nodes will allow reconstruction of pollutant flow and the density profiles of pollutants across the (3D) space.

[3] Discusses a novel technique which is used to measure Carbon Monoxide and Carbon Dioxide levels in an indoor environment using the infrared absorption principle. The proposed system also uses a PIC microcontroller for data acquisition. Our proposed design uses a MSP430F2274 microcontroller to use its capability of functioning in low power modes. The particular microcontroller has 5 low power modes to suit the requirements of the application. But the design in [3] lacks accuracy due to the relative newness of the idea. More research is required to enhance the robustness and accuracy of the sensor node. [4] Describes use of a singleSB-95 sensor to detect two gases, carbon monoxide and methane. The use of sensor is unique as, the same sensor detects two different gases for two different temperatures but the response to any one particular gas is delayed, because of the lack of the ability of the sensor to detect the two gases simultaneously.

The remainder of the paper is organized as follows. Section II describes the specific characteristics the sensor node should possess for the desired application. Section III describes the selection of hardware and the algorithm of the code dumped into the nodes. Section IV displays a sample application to test the establishment and efficiency of the

3 Sensor Node Design Requirements

The primary requirement of the sensor node is that it should have low power consumption. Hence hardware component selection should be done keeping in mind their compatibility with the power requirements of the node. Low power consumption will prolong the life of the node, making it apt for actual implementation.

Further to elongate the life of the node, we need to select sensors which need not be replaced in frequent intervals. For the specific application we need sensors to have a lifetime in years. Since many of the gas sensors rely on depletable reactive elements, they need to be replaced more than once a year. This makes them undesirable for our specific application. Also we need to keep in mind the fact that the design requires a collection of greater than 50 nodes which necessitates use of low cost sensors. All these factors will be taken into consideration while selecting the sensor for our application.

To enhance the robustness of the sensor node, it is important that the sensor is responsive at high temperatures, in the range of -20oC to 50oC. This temperature range will be suitable for our design because most of the environmental conditions will be in this particular temperature range.

The last requirement of the sensor node is to have a two way communication with the central computer system. This will allow the user to control the inaccessible sensor node from a distant location in case of varying environmental conditions. Also the user will have the capability of disabling the sensor nodes in case of an emergency like horrid weather conditions or natural calamities.

4 III.

5 Test Module, Coding Algorithm and Hardware Selection

To test the working our proposed design, we intend to use evaluation module EZ430-RF2500 provided by Texas Instruments. The module contains a set of two target boards, one assigned as access point and the other as end device. The access point target board is connected to central computer system using a USB port. The USB port provides the power supply for the access point. The end device is powered by two AAA batteries, each 1.5V. The module EZ430-RF2500 has an inbuilt temperature sensor which provides accurate readings in the range of ±0.1oC. Each target board consists of the following components.

6 ? A microcontroller (MSP430F2274)

? A RF transceiver chip (CC2500)? A chip antenna

The evaluation module also contains a software simulator (IAR embedded workbench) to debug and dump the code into the target boards. The module uses SimpliciTI protocol to develop RF communication among the target boards. The protocol can easily handle 100 nodes or more and hence is perfect for our particular application. The protocol provides with the option of using range extenders to increase the detection range of the target boards. The range extension can be done up to 4 hops. The communication topology used in the SimpliciTI protocol depends upon the target boards which are active. If both the access point and end device are in ON condition, store and forward peer to peer protocol is used. Else when only end devices are in ON condition, peer to peer protocol is used. The major advantage of using the SimpliciTI protocol is that there is very less latency in the response to the input from sensor nodes. Also as mentioned earlier, the protocol can handle large number of nodes which will help us in carrying out the reconstruction of pollutant flow and the density profiles of pollutants across the (3D) space. Now we will be discussing the various components which are going to be used in the sensor node. Following is the block diagram of the proposed design for our sensor nodes. Year configurable operational amplifiers. The microcontroller has one active and five software selectable modes of operation. Low power mode 3 is selected for the microcontroller in which the CPU, Main Clock and the Sub-Main Clock are disabled. The Auxiliary Clock is the only clock which is active. The microcontroller also contains a 10-bit A/D with integrated reference which will be very useful to convert the received analog values from the Carbon Monoxide gas sensor into microcontroller compatible digital values. Additionally, the microcontroller has an exceptional capability of waking up from standby mode in less than 0.1 ?s. All these specifications make the MSP430F2274 a perfect choice for our application.

RF transceiver chip CC2500 is used for the purpose of communication among the nodes. CC2500 is a low cost low power RF transceiver which is suitable for most of the common day applications. It operates in the 2400-2483.5 MHz ISM/SRD band system. The chip operates in the range of -40oC to 85oC which increases the robustness of our sensor node. Also the CC2500 has a built in analog temperature sensor, which assists in reducing the cost of the sensor node, simultaneously providing us with the option of monitoring a new physical parameter. Additionally, the chip has low current consumption and high sensitivity.

The code which is dumped into the target boards of EZ430-RF2500 too are of immense importance, as they provide possibilities of increasing the accuracy and decreasing the power consumption of the sensor nodes. To understand the code we need to know that both access point and end device have separate codes dumped into them. Due to limited hardware semaphores are used, which enable maximum extraction out of the possible hardware. The factory code contains 3 semaphores sJoinSem, sSelfMeasureSem and sPeerFrameSem. The function of semaphore is to limit the hardware to only one specific function at any particular time. This means that if at any moment, anyone of the semaphore is set, the other two have to be low.

The three semaphores are used for three different purposes. The semaphore sJoinSem is set every time an end device attempts to join the network. The semaphore sPeerFrameSem is set when the end device sends a frame to the access point. These frames contain the data acquired from the Carbon Monoxide sensor. The semaphore sSelfMeasureSem is set when the access point needs to measure the temperature using its inbuilt temperature sensor. Since our central computer systems do not require an interface with the gas sensor, we can ignore and remove the sSelfMeasureSem semaphore to increase the efficiency of our code. The semaphore technique increases the responsiveness of the network as all the end devices can attach themselves to the network at any point of time.

The flowchart below describes the code algorithm for the access point node. As described before, setting high of a semaphore depends on the activity shown from the end device. Thus the code is responsive to any activity from the end device ay any point of time, decreasing the latency in the network.

7 Working and Discussion

To test the response of our network, we used the evaluation module EZ430-RF2500. Input was fed from the end device using switches, response to which was viewed on a laptop and also simultaneously using two LEDs. In figure [5] we notice two target boards. The target board on the right, from where the input is provided using switches, is the end device. The target board on the left is the access point. The end device transmits the value of 0 or 1 depending upon the input given from the switch. The same Input is later reflected on the console window, displaying the values of 0 or 1. The red and green LEDs glow separately in response to the different input values provided by the end device. If no input is provided, the console window displays the default message "NO SWITCH WAS PRESSED". Also each message contains information about the received signal strength from the end device. These values can be used to estimate (but not accurately determine) the distance of the sensor node from the central computer system or the access point.

Life expectance vs. Transmission Period [13] Life expectancy of the sensor node is a very essential characteristic for our specific application. Increasing the lifetime of the sensor node would imply less frequent replacement of power supply sources at the remote areas where the sensor node is established. The above graph displays a technique which can be used to increase the lifetime of the sensor node. If the time difference between two transmissions is increased, the life expectance of the sensor nodes can be stretched to 40 years [13].

V.

8 Conclusion

This paper presents a technique to design robust sensors with increased lifetimes. The ability of the sensor network to handle a large number of nodes will help in carrying out various processes of environment monitoring like reconstruction of pollutant flow and the density profiles of pollutants across the space. Hence the technique provides new opportunities to explore new ways of monitoring the gaseous pollutants, especially carbon monoxide in the air space. In the same way any other parameter may be efficiently detected by developing an appropriate sensing node. Although the fabrication results are not provided, actual implementation of this technique will help by providing more insights on ways to improve the accuracy of the readings of the carbon monoxide sensor, while simultaneously keeping the cost factor to a minimum.

9 VI.

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Figure 1:

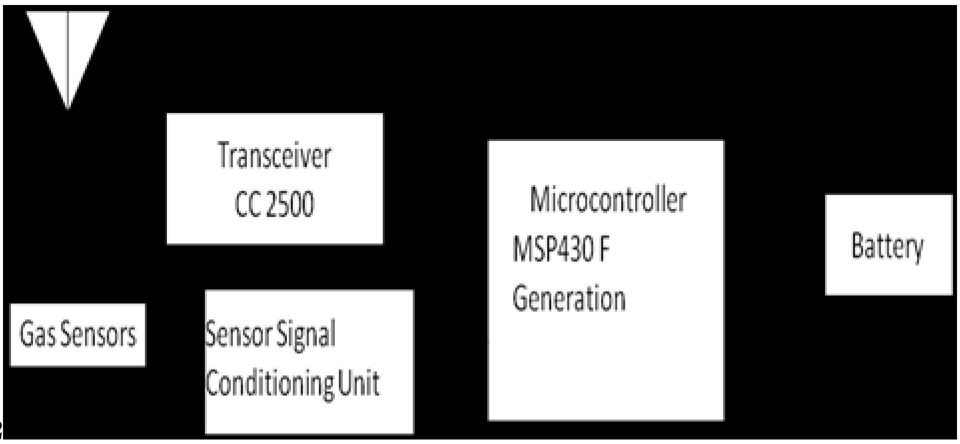

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Figure 2: Figure 1 :Figure 2 :

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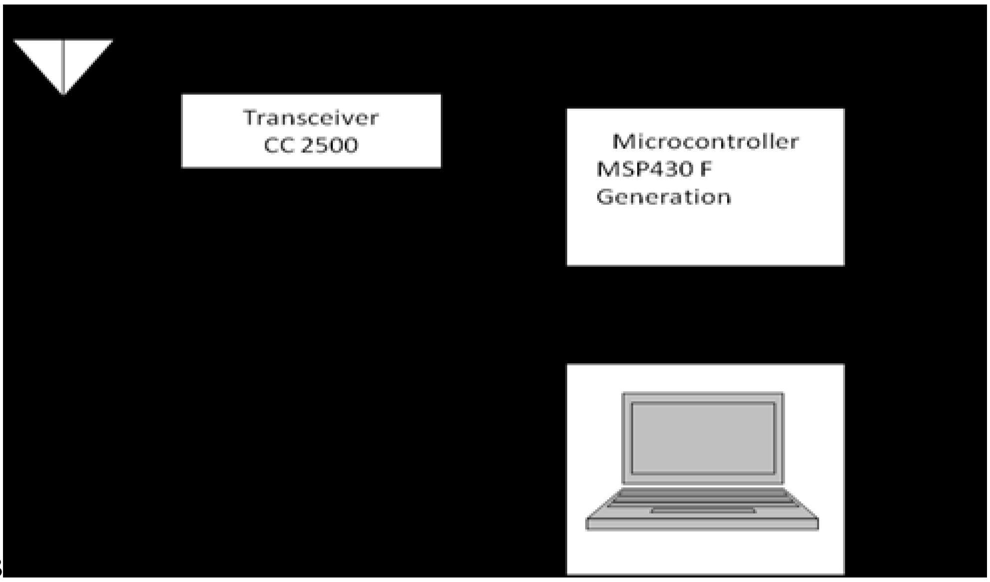

Figure 3: Figure 3 :

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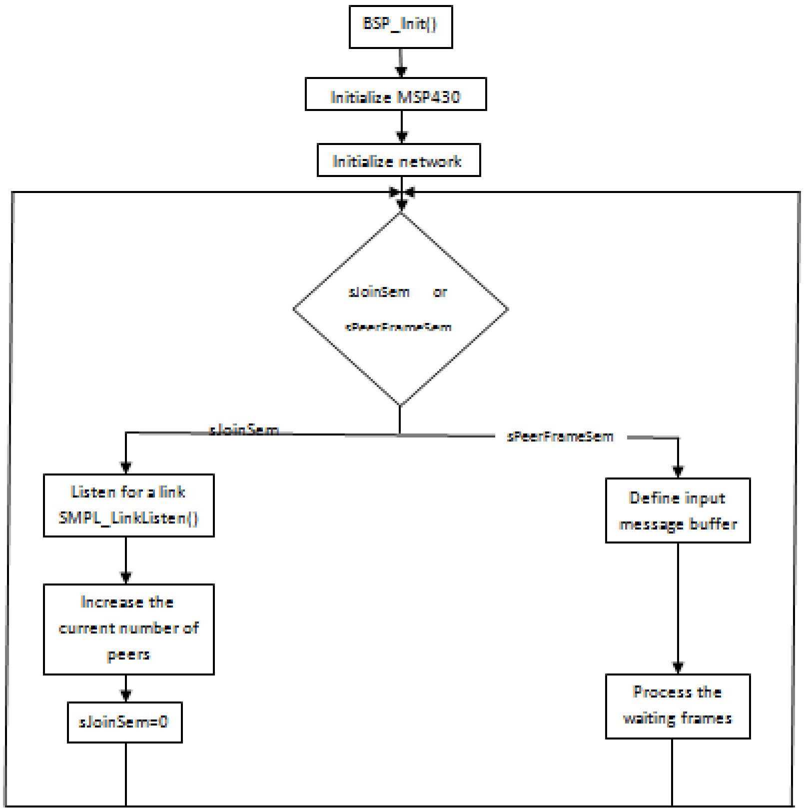

Figure 4: Figure 4 :

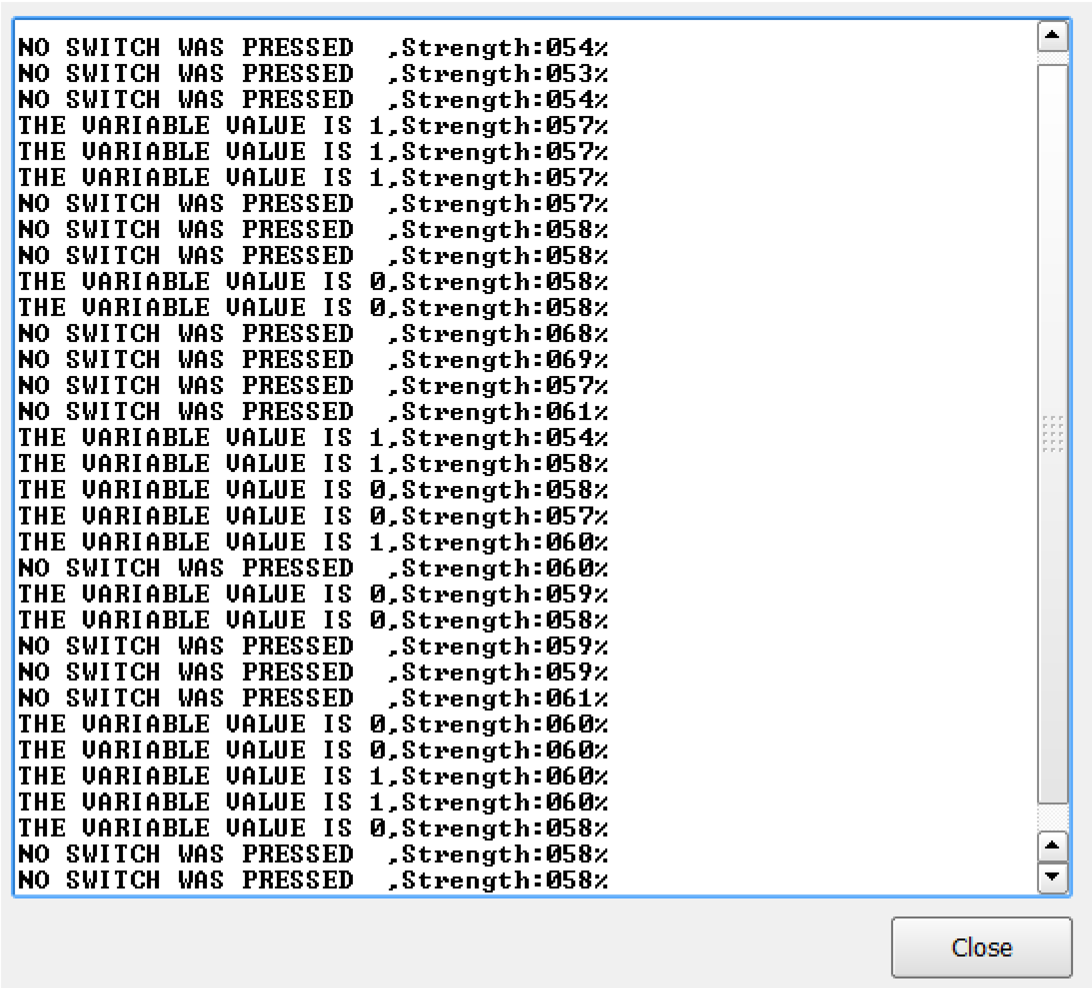

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Figure 5: Figure 5 :

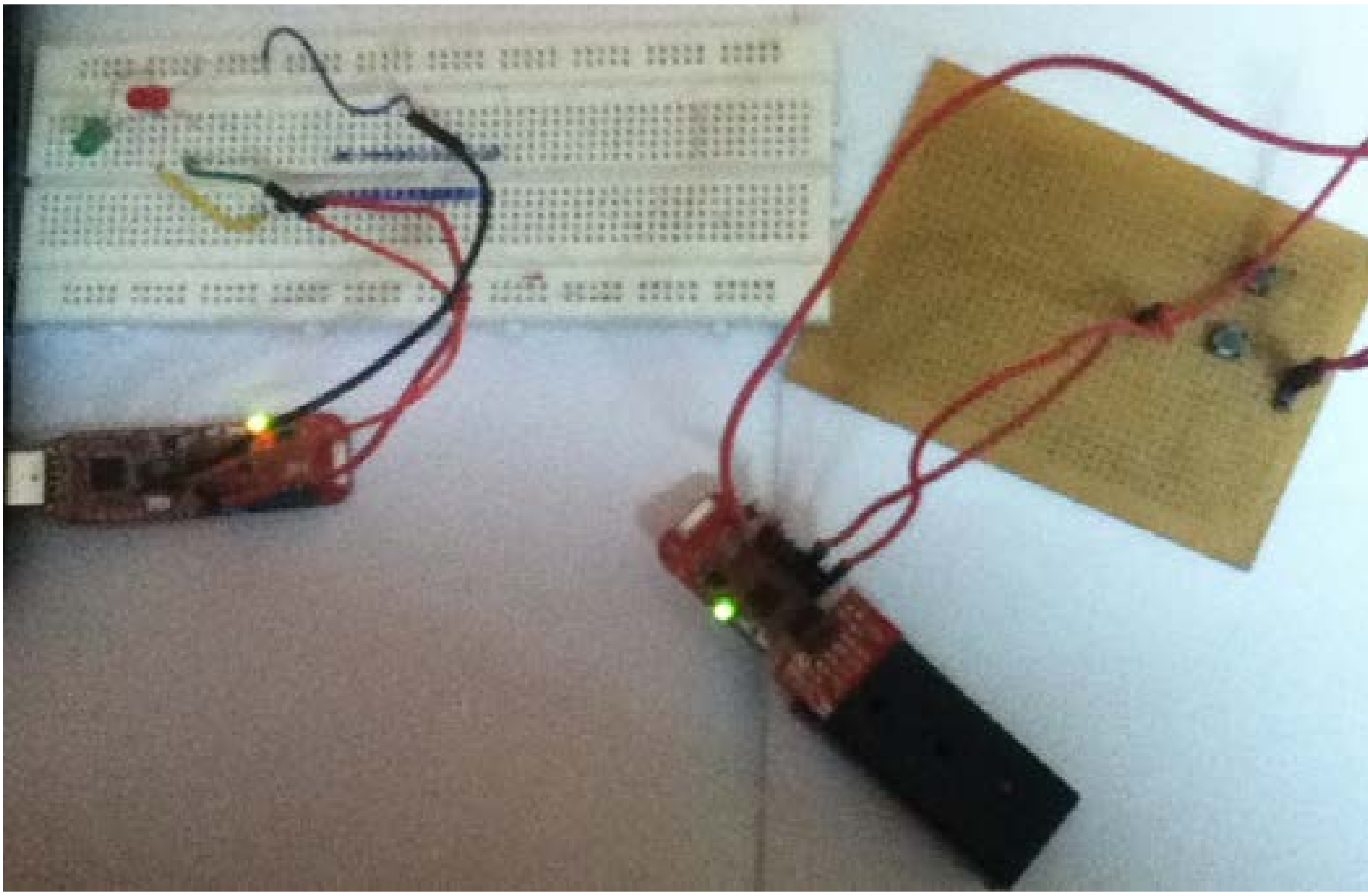

Figure 6:

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.1 Acknowledgement

The facilities offered in the Electronics Laboratory in VIT University are thankfully acknowledged.

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