ABSTRACT — High levels of carbon dioxide (CO$_2$) aboard the International Space Station (ISS) have been reported to cause cognitive impairments among its crewmembers. Jet Propulsion Laboratories (JPL) proposed a project to create a wireless carbon dioxide sensor array to measure CO$_2$ levels in the environment. The network that will be used for this array will be ZigBee. Nodes will be comprised of the CO$_2$ sensor, an Arduino, and an XBee Transceiver. These nodes will be programmed according to their role as a coordinator, router, or end device. The array will collect and deliver data in real time. The data will be displayed in a Graphical User Interface and will allow crewmembers to monitor and adjust the air quality as needed.

I. INTRODUCTION

The primary use of the International Space Station (ISS) is to allow crewmembers to conduct research and experiments in a zero-gravity environment. There are 10 long term countries associated with the ISS, but other countries have also worked inside the structure. Jet Propulsion Laborites has stated an issue within the International Space Station (ISS) where high levels of carbon dioxide (CO$_2$) have caused cognitive impairment among its crewmembers. The team has been tasked with designing a wireless carbon dioxide sensor array. This array will output real time data for the crewmembers on the ISS to monitor their environment and adjust the air quality as needed.

Similar work has been done on the ISS to detect the location of crewmembers and measure the temperature and humidity in their environment using an Impulse-Radio Ultra-Wideband network. Although similar, the selected design for the CO$_2$ array uses a ZigBee network. Some constraints that will be considered while designing this array are the need for message relaying given the size of the ISS and given the concern that RF signals be absorbed easily due to the material of the ISS, and the concern of the network being able to operate together with the WI-FI network already in place in the ISS. This project will have a positive impact because it will allow the understanding of CO$_2$ level variations within the ISS and the effect it can have on a person’s cognitive impairment.

II. NETWORK

The selected design for the CO$_2$ array will use a ZigBee network. ZigBee is a set of communication protocols for low-data-rate wireless networking, particularly suitable for wireless sensor networks [1]. ZigBee was the chosen network for the sensor array because of its mesh capabilities, IEEE security protocol, an overall full network stack, and the availability of ZigBee devices in the market. Zigbee’s mesh network requires three types of nodes: the coordinator, end devices, and routers. Figure 1 illustrates how these nodes interact with each other to make up the network.

Figure 1 Network Setup

The coordinator will collect incoming data from the routers and transmit to the main central processing unit (CPU). The end device will collect data from the CO$_2$ sensor and transmit that data to the router which relays messages from the end device to the coordinator.
These nodes are connected using a mesh network topology to transmit data between them. A mesh network is a local network topology in which the infrastructure nodes allow for easy expansion because they do not require that all nodes be within reach of the coordinator, allowing as many other nodes as needed to route data to and from clients.

Zigbee also has reliable data transfer. This comes from the network protocol by having the devices create acknowledgements and from a mesh network because all the devices are interconnected. A benefit of nodes being interconnected with each other is that the network can “self-heal.” This is possible because in a mesh topology, data routes are created on demand and have the ability to alter those routes if there is a change in the environment [2], so if one router node fails, the data can be re-routed using a different path.

ZigBee’s expandability, maturity, ability to extend the range of the network by relaying packets, and the full protocol network stack make it a suitable network for this array.

III. DEVICES AND SOFTWARE

Each node is constructed using an Arduino Mega, a shield board, and an XBee S2C transceiver. The Arduino Mega is the microcontroller that will be used to receive the data from the CO₂ sensor and send it to the transceiver. The Xbee transceiver will be installed on top of the Arduino Mega using the shield board.

![Node Configuration](Figure2.jpg)

**Figure 2**

Node Configuration

The programming software that will be used is XCTU. XCTU is designed to allow interaction with ZigBee Pro modules through a simple graphical interface. The program will also allow the management and configuration of RF devices, firmware updates, and create communication with radio devices. XCTU is important for the final purpose of expanding the network through additional devices [3]. The Arduino Mega will be programmed in C language. The C programming language was chosen because it offers functions, loops, arrays, and all other essentials for low-level programming.

The data that is collected will be displayed using a graphical user interface (GUI). Python will be used to program the GUI because it has existing libraries that are strictly chosen for the GUI and due to the syntax, it has easy implementation.

IV. CONCLUSION

Currently, there is no wireless carbon dioxide sensor array integrated into the ISS. This CO₂ sensor array design for Jet Propulsion Laboratory will monitor the carbon dioxide levels in the ISS and distribute the data in real-time. This can help prevent high levels of carbon dioxide which has been reported to cause cognitive impairment and other adverse effects among the crewmembers of the ISS. The implementation of this array will allow the air aboard the ISS to be monitored and adjusted as needed.

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