ZigBee Mesh and Graphical User Interface for a Wireless Tunable Laser Spectrometer Array Onboard the International Space Station

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Abstract

Astronauts working onboard the International Space Station have reported recurring health issues that are potentially related to exposure of high levels of carbon dioxide. However, there currently is not a robust and reliable way to monitor the concentrations that astronauts are experiencing. Some studies suggest that long-term exposure to high levels of carbon dioxide can cause bone and kidney composition changes, chronic inflammation, and vision impairment, with short-term issues such as dizziness, lethargy, increased blood pressure, and headaches. Because exposure to high levels of carbon dioxide can result in these long and short-term health issues, it is important to measure carbon dioxide and other trace gases in real-time over a system-wide spatiotemporal range to provide an understanding of areas and times of high carbon dioxide accumulation.

Introduction

A more extensive means of tracking carbon dioxide concentrations in real-time onboard the ISS is required. Wirelessly transmitting tunable laser spectrometer sensor readings and performance metrics in a ZigBee mesh network to a base station graphical user interface is the proposed solution.

Project Objectives:

- Customize microcontrollers connected ZigBee communication modules to wirelessly transmit network health metrics and spatiotemporal distributions of carbon dioxide.
- Actively minimize radiofrequency interference and coexist with other wireless communications operating on the same 2.4-2.5GHz band.
- Design a base station graphical user interface to collect, visualize, and record data from all nodes.

Methods and Materials

Wireless communication modules flashed with ZigBee protocol firmware were attached to serial communication pins on customized printed circuit boards with AVR microcontrollers. The microcontroller programming collects data from the attached sensor, as well as various network health metrics from its local ZigBee module, and then formats the data into ZigBee packet payloads for RF transmission to the network's coordinator connected to the base station's serial port. The base station programming then parses through the received data, displays it in real-time graphs, and exports it for data analysis.

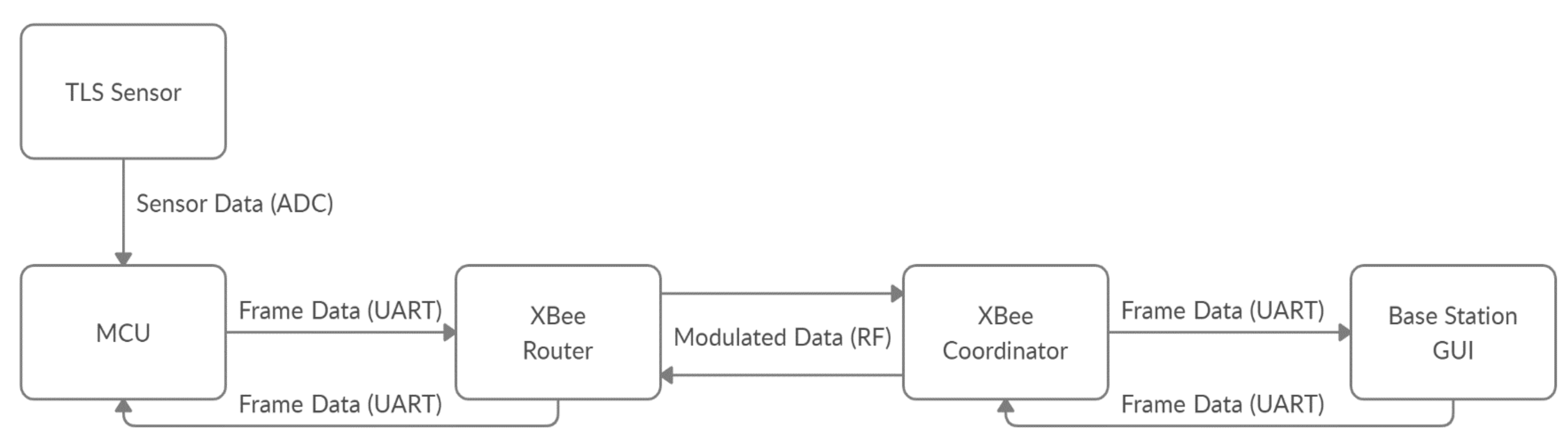

Figure 1. Network Block Diagram

Results

Table 1 summarizes test results from running the network at low RF Rx/Tx power (-1dBm) in a controlled environment with and without interference on the same network operating frequency.
It is observed that the network performs best in star-configuration (one-hop) without interference.

Condition	Test Configuration	Packets	Retries	BufferCnt	Failures
Noise-Free	Star	6933	172	29	0
Noise-Free	Multihop	6933	1240	50	26
High-Noise	Star	6933	1980	59	0
High-Noise	Multihop	6933	4660	259	34

Figure 2. Test Results

Discussion

- With low noise/interference on the same channel, the network can reliably transmit data in real-time at a rate of 1Hz through multiple hops with nearly 0% packet loss.
- With high noise/interference on the same channel, data is still collected properly but retries and latency are substantially increased.
- To improve network reliability and ensure low latency between packet transmissions, the network must operate on a low-noise channel.

Conclusions

- Payloads have been optimized to allow the network to perform as efficiently as possible.
- In the event of a transmission timeout and/or failure, the timeout buffer will retransmit data – ensuring 0% data loss.
- To combat compromised network integrity, we designed a 2.4-2.5GHz spectrum analysis algorithm that can reliably detect network interference and change to a noise-free channel to operate on, which allows for buffered data to be transmitted after a network reset.

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