Analyzing Amazon Sidewalk FSK Protocol

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Introduction

Background
- Amazon Sidewalk:
  - Low-bandwidth mesh Internet of Things (IoT) network
  - home automation and security
  - New proprietary FSK (Frequency Shift Keying) communication protocol

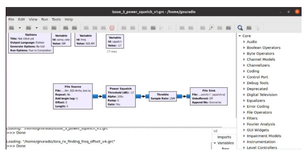
Research Goal
- Dissect and analyze the Amazon Sidewalk FSK Protocol
- Create a framework for analyzing IoT signals in general
- Important for:
  - Analyzing IoT traffic patterns
  - Evaluating IoT security/privacy

Challenges
- IoT protocols proprietary with little documentation publicly available
- Signals are:
  - Sparse/short in time domain
  - Separated on different frequency channels
  - Encoded with variable encoding schemes

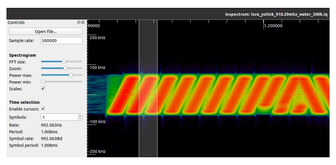
Methodology

This project focuses on building a platform to analyze Software-Defined Radio (SDR)-captured waveforms using the GNU Radio Companion.

Software Setup
- OS: Ubuntu (Linux)
  - Both native Ubuntu and a pre-built Docker file were tested
  - Pre-built Docker image
- Collaboration: GitHub Repository
- Software Tools:
  - GNU Radio: Flowgraph-based programmable radio design

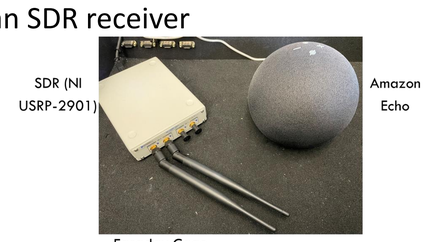


  - Inspectrum: Spectrogram (frequency versus time) for recorded radio signals; analyzes modulation of waveforms; generates decoded bitstream



  - Sublime: Python/C++ editor
  - Universal Radio Hacker (URH): automatic radio signal analysis
  - CRC RevEng: Python-evoked tool for reverse engineering Cyclic Redundancy Check (CRC) error correction codes

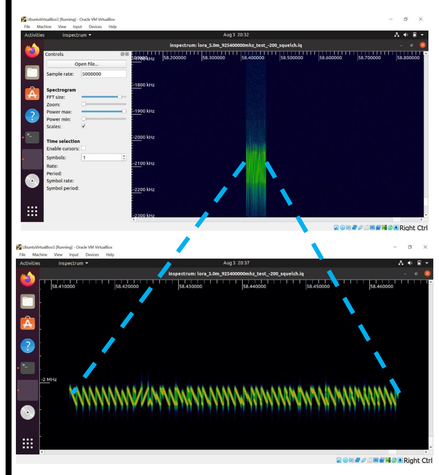
Experimental Setup
- Amazon Echo isolated in a Faraday cage next to an SDR receiver

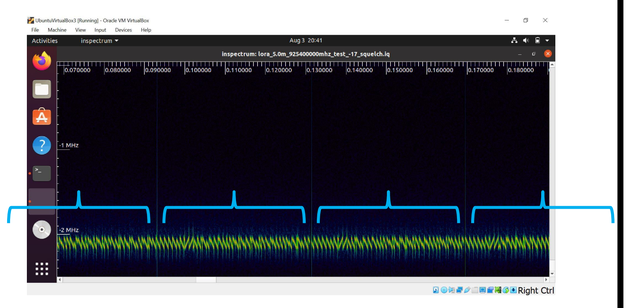


Faraday Cage

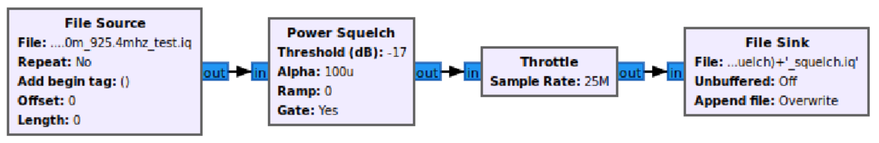
Results

Step 1 Finding Data Packets in Time





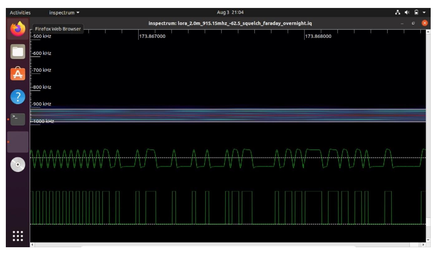
- Received data packets are sparse
- Want packets to be back-to-back in the time dimension
- Input: raw signal capture
- Power Squelch block: threshold on signal energy to detect sections with valid data
- Output: file of back-to-back packets



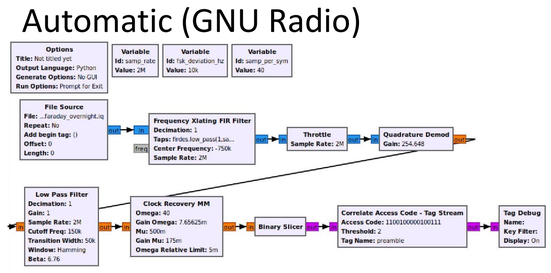
Step 2 Detect packet frequency channel and convert to digital

Part 1: Recovering data bits on known fixed channel
- Shift to known channel and filter
- Latch onto preamble alternating bits as a clock
- Use clock to find bit boundaries and determine if each is a 1 or 0

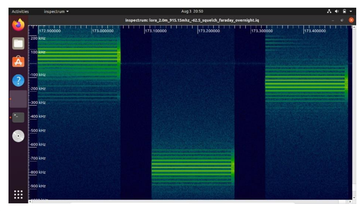
Manual (Inspectrum)

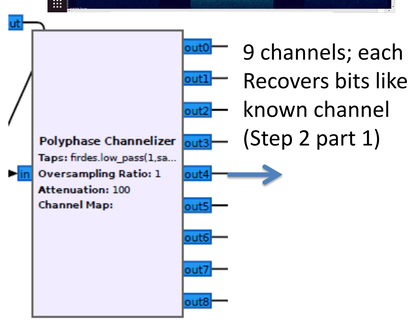


Automatic (GNU Radio)



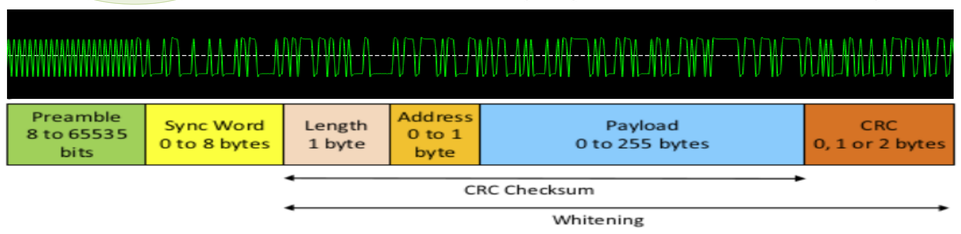
Part 2: Finding the channel
- Input: analog packets from Step 1
- Polyphase Channelizer block:
  - Divides bandwidth into multiple channels
  - Routes inputs to proper channels
  - Replicates bit recovery (part 1) on each channel
- Output: digital binary data





9 channels; each Recovers bits like known channel (Step 2 part 1)

Step 3 Find and extract payload from binary



CRC (Cyclic Redundancy Check) detection:

Python / CRC RevEng:
- Python code loops through possible payload lengths and payload/CRC positions for 4+ different data+CRC strings
- Feeds to CRC RevEng to find CRC that matches
- Also try:
  - Different CRC lengths
  - Invert CRC bits (bitwise XOR)

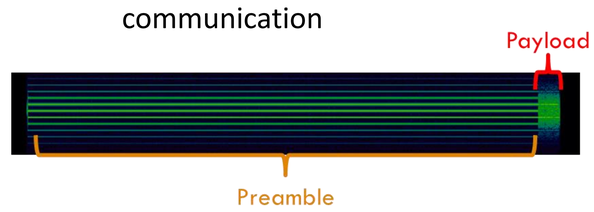
Universal Radio Hacker (URH):
- URH can generate and check CRCs by testing different CRC parameters and other checksums
- Representations such as bit, hex, and ASCII viewable in URH can also be used to help identify CRCs

Discussion/ Conclusions

Accomplishments:
- Captured wireless signals of the Amazon's FSK radio and YoLink's LoRa protocols using SDR and analyzed them in Inspectrum
- Created programmable method of capturing, channelizing, and decoding FSK packets of Amazon Sidewalk
- Demonstrated both manual (Inspectrum + Python) and automatic (GNU Radio / Universal Radio Hacker) methods of processing packets
  - Manual: easier to grasp at first
  - Automatic: better for large-scale operations
- Extracted packet features like center frequency, bandwidth, bitrate, etc.
- Attempted to reverse engineer CRC (cyclic redundancy check) using RevEng tool

Future Research:
- Finding exact CRC algorithm and automatically validating CRC in GNU Radio
- Implementing real-time GNU Radio receiver automating packet processing from input signal to outputted payload data

Discussion:
- Long preamble with respect to packet size
  - Conjecture: reliable long range communication



- Fixed portions across several packets from same device can help with detecting encoding schemes (especially the sync word) and identifying possible sources
- Power-based packet detection was only tested for single channel case without multiple packets coming in simultaneously
- Same setup applicable to other IoT protocols
  - Steps customizable for different signal strengths, channels, and encoding schemes

Acknowledgements

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