Phase 1 Specification

ZVALS - group 10
Connor Klies, Sam Mansouri, Matthew Calim, Asaf Iron-Jobles, Reshmi Nilus

Equipment

- 4 HackRF SDRs
- 3 coax antenna mounts
- 4 telescoping whip antennas
- 2 Laptops (also required for the demonstration)

Objective

The objective of phase 1 is to design, implement, and demonstrate a time-division multiple access (TDMA) wireless link using four HackRF software-defined radios (SDRs). Three of the SDRs are to act as receivers with the last SDR acting as the sole transmitting node. The receivers will use time of arrival (TOA) and/or frequency offset (CFO) to triangulate the position of the transmitter node relative to one of the receiver nodes. The link is to be robust indoors, under the effect of doppler (transmitter node moving), and through obstacles. Phase 1 focuses on the robustness and correctness of the RF link more so than the triangulation as proof of concept.

Systems Overview

Nodes:
- 3 receiver HackRFs in a triangle pattern half a wavelength of our carrier frequency apart
- 1 transmitter HackRF that is mobile

Multiple Access Scheme:
- TDMA with a fixed repeating frame structure i.e. time windows, guard intervals, and assigned nodes remain fixed for the lifetime of the link
- Single frequency channel shared in time

RF specifications:
- Frequency channel centered at 915 MHz (902-928 MHz ISM band)
- At most usage of 10 MHz of bandwidth (better for time division multiple access)
- Frequency of interest from 905-925 MHz
- QPSK modulation → 2 bits/symbol

- No FEC in this phase

Tests:

- All done indoors → multipath
- Static channel in direct LOS at variable ranges of both wavelength multiples and non-wavelength multiples
- Static channel in non-LOS again at the same variable ranges
- Transmitter in random motion (doppler effect) in direct LOS and non-LOS

Requirements

TDMA Frame Structure Requirements:

The transmitter node shall transmit packets in periodic time slots within a TDMA frame. The frame shall contain a known (to the receiver) preamble, a known pilot sequence (carrier frequency offset estimation), and payload (dummy bytes for phase 1). Slot timing shall be determined by sensor poll rate, ground station processing time, HackRF tx/rx switching time, and guard interval.

Receiver Node Requirements:

The receiver nodes shall all independently detect the frame using the known preamble, and use the pilot sequence to estimate and correct CFO. Clock synchronization between the three nodes is not a requirement for this phase.

Each receiver shall determine TOA and frequency offset independently and calculate the relative position of the transmitter to the receiver origin node. The accuracy is not important for this phase as it will require using the raspberry PI's onboard clock to synchronize all receiver nodes to have accurate triangulation in later phases.

Doppler Robustness Requirements:

When the transmitter node is in motion in variable conditions (LOS/non-LOS, indoors/outdoors, and regardless of velocity consistency), the receivers shall be able to reliably receive packets and decode the dummy bytes. Furthermore, the receiver nodes shall roughly triangulate the transmitter regardless of doppler and other conditions.

Deliverables

1. Live demonstration of the working link with the transmitter node in motion. Receiver nodes detecting frames properly and maintaining constant reception
2. Receivers will have the following signal processing chain: bandpass → timing synchronization via preamble detection (matched filtering) → CFO estimation using pilots (again matched filtering) → slot based packet detection
3. Consistent (precise not necessarily accurate) time of arrival and frequency offset measurements at each receiver.
4. Demonstration of the TDMA waveform plus verification of matching preamble, pilot sequences, and dummy bytes by the receiver in a reproducible manner.

Next Steps

Phase 2 will focus exclusively on making the link bi-directional between the soon-to-be ground station nodes and drone node. We will also clock synchronize the ground station nodes to improve ground station triangulation accuracy. Furthermore, we may transition to OFDM (orthogonal frequency division multiplexing) over TDM (time division multiplexing) for improved multi-path performance, better channel estimation and equalization, and better spectral efficiency. Ultimately, phase 2, will focus on integrating the STM32, raspberry pi and moving our PHY link to bi-directional and potentially OFDM, while our MAC (media access control) layer will remain TDMA.