HiPER-V: A High Precision Radio Frequency Vehicle for Aerial Measurements

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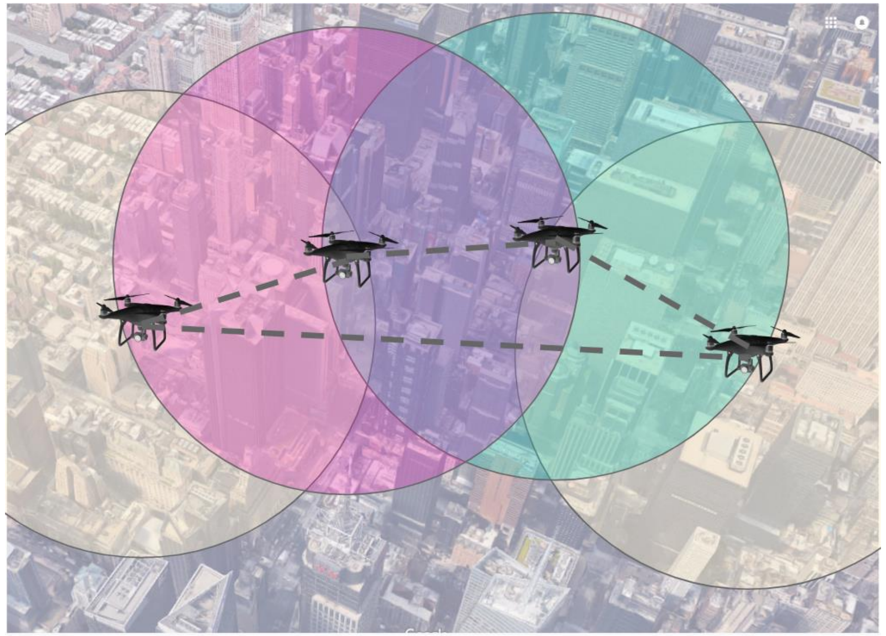
MESA

1. Introduction

Mobile Autonomous Agents for applications in wireless communications.

Unmanned Aerial Vehicles (UAVs)

- Autonomy and Broad visibility
- Constrained on resources
- Requires precise position information.



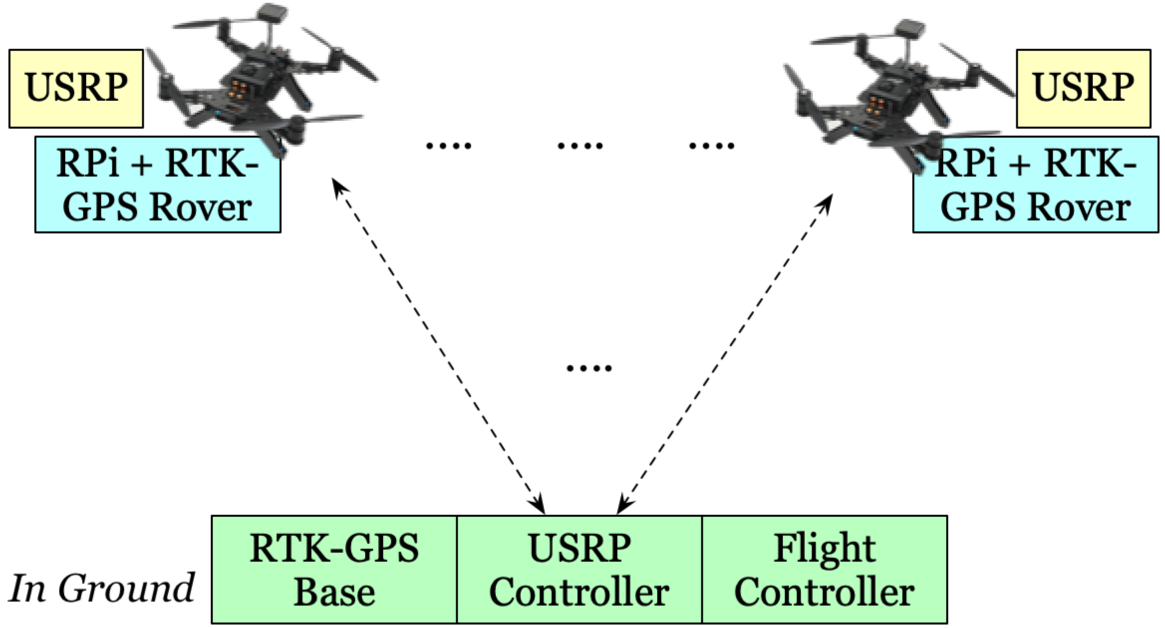
Swarm of UAVs for maximal coverage

HiPER-V: A generalized UAV prototype platform that achieves precise positioning to enable applications in wireless communications.

HiPER-V

HiPER-V: UAV mounted with a radio module and positioning modules.

Ground station: Flight control, Radio control, precision positioning base.



HiPER-V Prototype

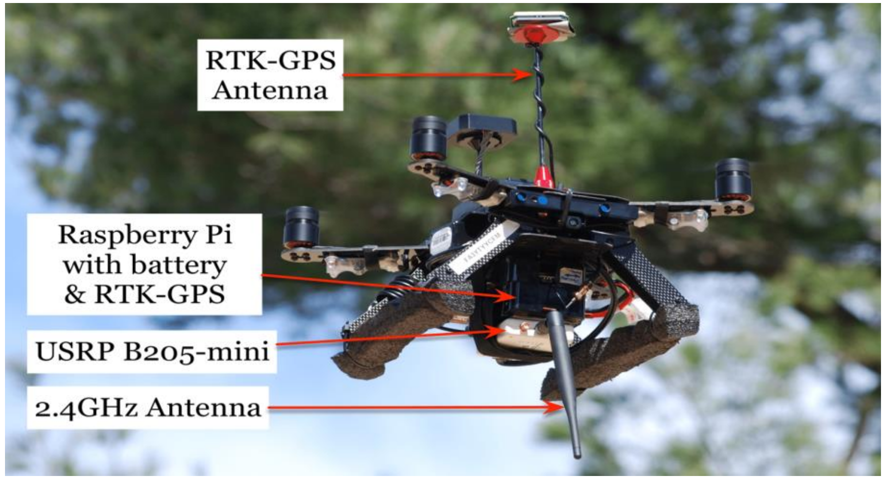
Generic Platform

General Purpose Hardware, Open Source Software.

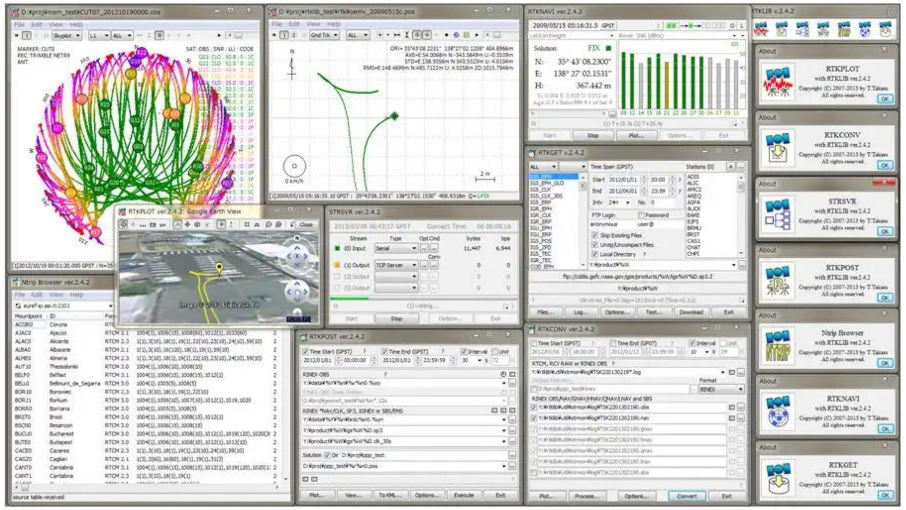
Autonomous precise flight control - Dronekit /MAVLink

Choice of Radio platform - Performance vs Resources

Precise Positioning - RTKLib



HiPER-V Prototype Implementation



RTKLib

UAV and Swarm based Applications

Practical deployment and validation.

Especially lucrative for applications that demand high precision positioning.

Single UAV applications - Optimal Placement, Navigation

Swarm UAV applications - Robust Collaboration

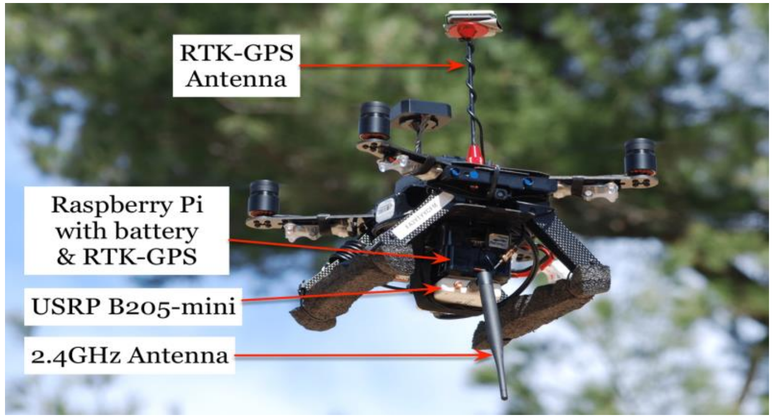
2. System Design

There are 3 key components in the system design of HIPER-V

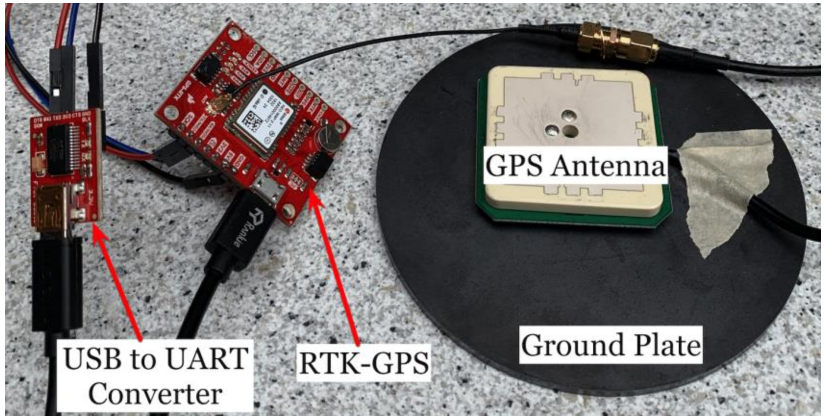
- UAV Flight Control
- RF Module of the UAV
- Positioning of the UAV

HiPER-V Implementation Details

- USRP B205mini used as RF module in our prototype
- Connected to Intel Aero Drone using USB
- 2 Sparkfun NEO-M8P2 modules used as base and rover modules
- Base GPS connected to ground laptop while rover GPS connected to Raspberry Pi



HIPER-V Prototype Implementation



U-Blox M8P2 used as ground GPS base

UAV Flight Control

UAV motion - depends on application

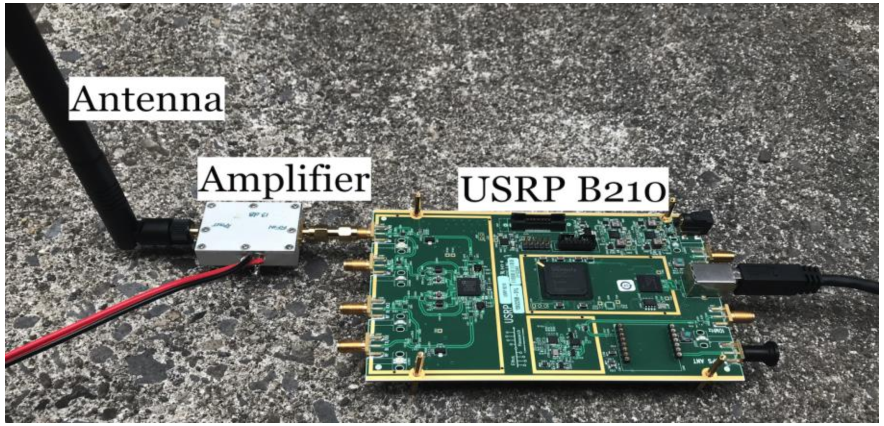
- Precise Movement - Dronekit-Python
- Random Movement - External factors

```
$ ./drone_fine_navigate
-- Connecting to vehicle on: tcp:127.0.0.1:5760
-- >>> APM:Copter V3.5.7 (d2c78176)
-- >>> PX4: b535f974 NuttX: 1bcae90b
-- >>> Frame: QUAD
-- >>> AEROFCv1 004D001F 33355118 39343335
-- Basic pre-arm checks
-- Waiting on vehicle to initialize...
-- Arming motors
-- Taking off
-- Setting Yaw Angle of 5 degrees
-- Setting Yaw Angle of 0 degrees
-- Landing
```

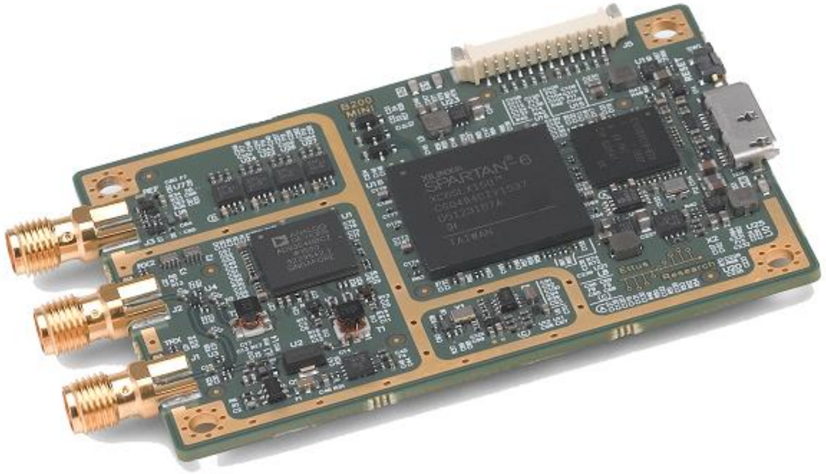
Output of precise movement script

RF Module

- For Communication or Signal Acquisition
- Software Defined Radios (SDR)
- B205mini used on UAV due to form factor
- Radio used can vary based on user's needs



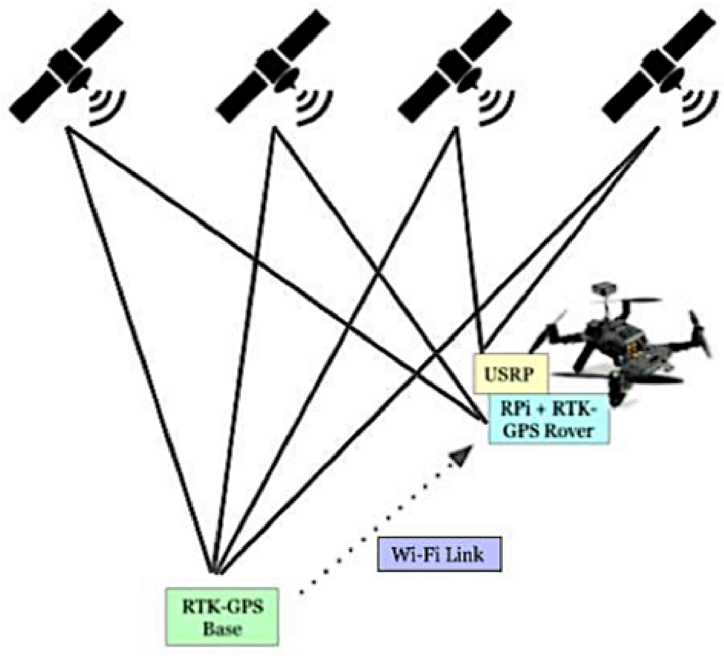
SDR Transmitter at Ground Controller



SDR used on HIPER-V UAV

Positioning of UAV

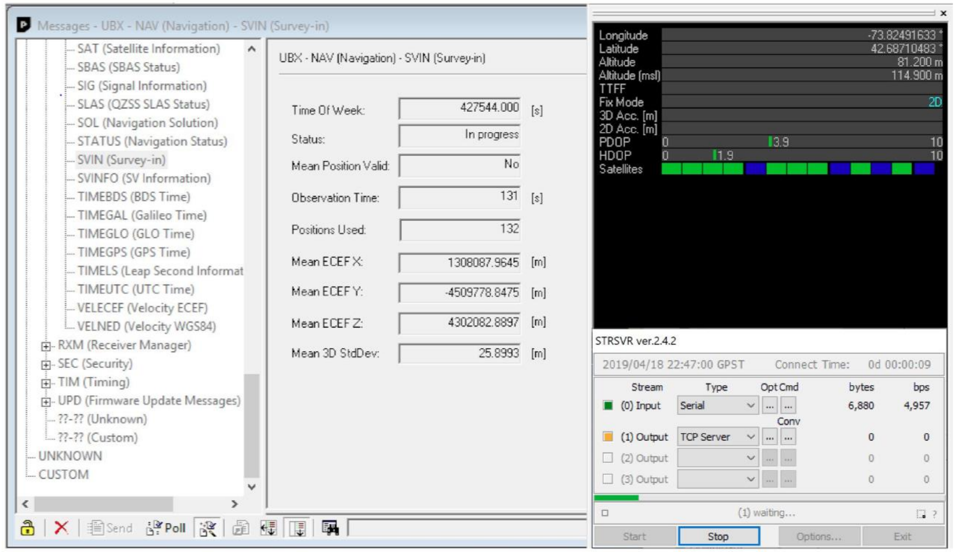
- HiPER-V positioning accuracy greater than standard UAVs
- Can achieve up to 2.5 cm level accuracy
- Wi-Fi communication link used in our HiPER-V prototype
- Doesn't need to be Wi-Fi, can be other type of link



RTK-GPS Implementation

RTK Setup

- Base GPS can either be configured through script or GUI
- Rover is configured through script on Raspberry Pi



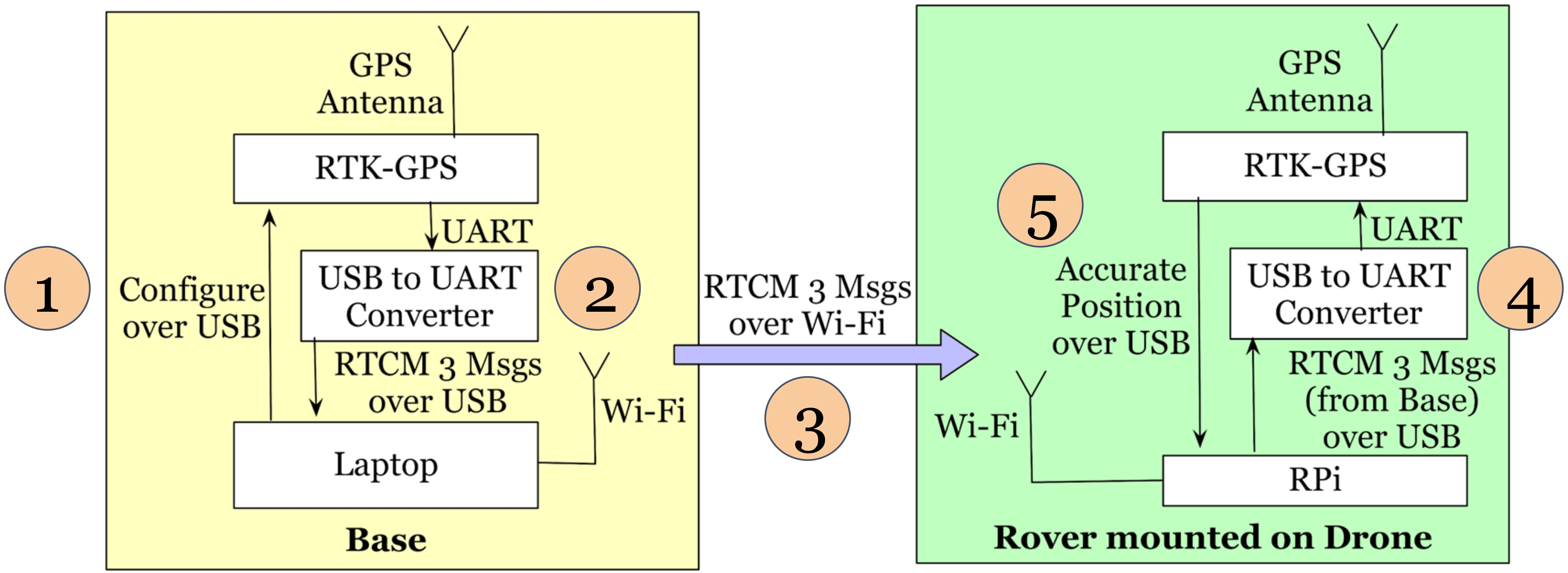

```
$ ./run_rtk_base
-- Required Accuracy: 1.5 meters
-- Observation Time: 300 seconds
-- Sending Message
-- Status:  In progress
-- Observation Time Passed: 14 seconds
-- Accuracy: 3.2925 meters
...
-- Status:  Successfully Finished
-- Observation Time Passed: 303 seconds
-- Accuracy: 1.49277 meters
```

RTK-GPS Base setup Output (Ground Controller)

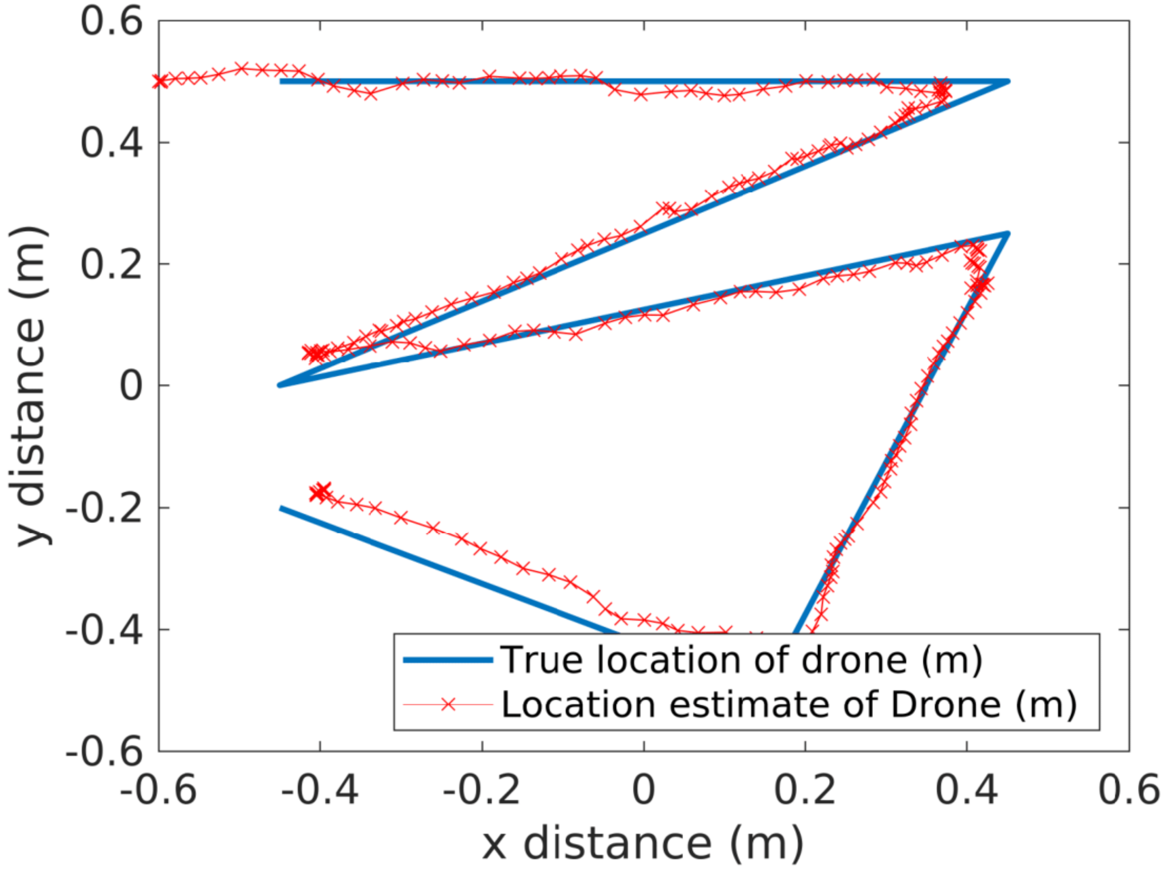
```
$ ./run_rtk_rover
--GPS Accuracy: 3.92 cm
--GPS Accuracy: 3.40 cm
...
--GPS Accuracy: 2.59 cm
--RTK Fix Achieved (below 2.5 cm accuracy)
--GPS Accuracy: 2.38 cm
```

RTK-GPS Rover Setup Output (Raspberry Pi)

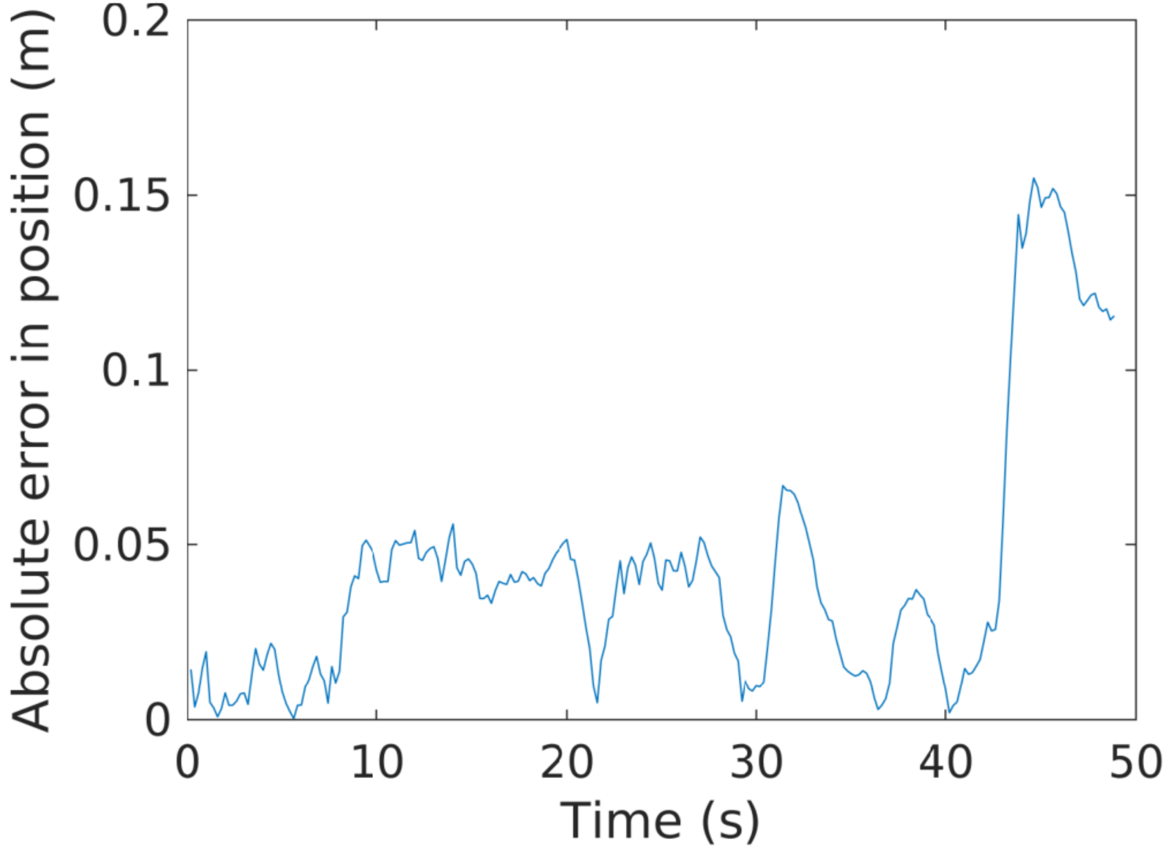
RTK Setup Block Diagram



Positional Performance

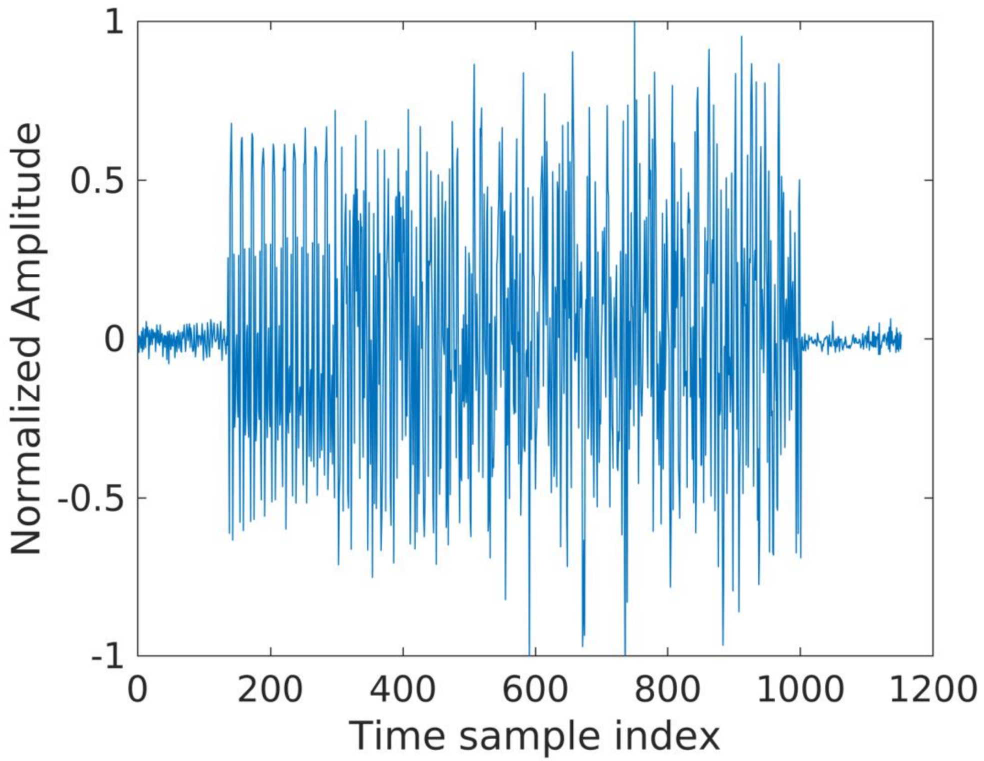


Expected vs Actual Positions of UAV

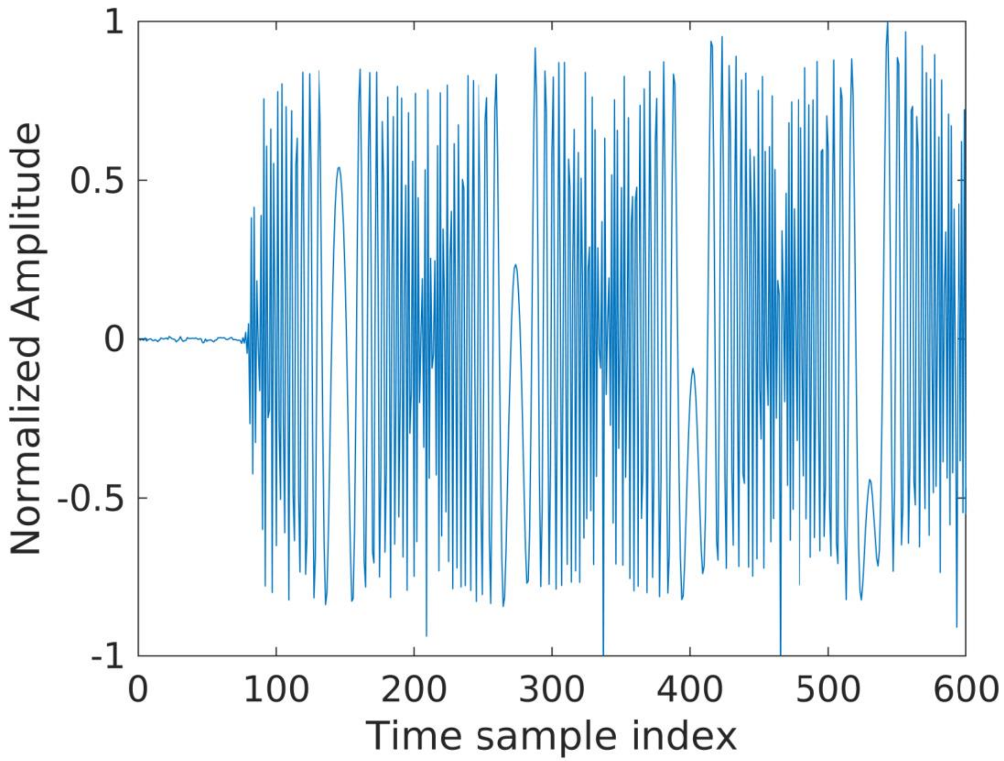


Drift in Accuracy Over Time

Sample Collection Performance



Received Wi-Fi



Received LoRa

3. UAVs for Wireless Communications

Accurate positioning for optimal placement, optimal navigation and cooperation.

Swarms of collaborative UAVs are more sensitive to position errors.

Applications:

- MIMO, Massive MIMO Distributed MIMO
- Collaborative beamforming
- Joint provision of service/connectivity
- Localization of RF transmitters

4. Related Work

Localizing The UAV

Infrastructured Approaches

- Optitrack
- RF Localization

Infrastructureless Approaches

- GNSS (Global Navigation Satellite System) based methods
- INS (Inertial Navigation System) based methods
- GNSS+INS based methods

Existing Testbeds

TABLE I: Comparing HiPER-V with existing wireless testbeds

Testbed	Task	Equipment	Positioning
[22] [23]	Adhoc network among multiple UAVs	Raspberry pi, Parrot Ar. Drone Custom telemaster based plane	GPS based GNSS
[24]	Accuracy of the navigation system	AirRobot quadrotor simulation	GPS-INS
[25]	Aerial localization	Draganflyer X6, Nokia N900	GPS based GNSS
[26]	Controlling the UAV path to improve link quality between mobile nodes	NexSTAR unmanned aircraft	GPS based GNSS
HiPER-V	A wide range of wireless communication applications	Can be ported to any system of UAVs, SDRs and RTK-GPS modules	high precision RTK-GPS based

"HiPER-V is the first platform to facilitate practical wireless communications that require precise positioning of the UAV in resource constrained UAVs"

5. Conclusion

- HiPER-V prototype platform to enable various wireless communication applications, which uses resource constrained devices.
- High precision RTK-GPS for accurate positioning.
- Platform is based on commodity hardware and open-source software.
- Code available on Github and the website.

Thank you

Questions & Feedback