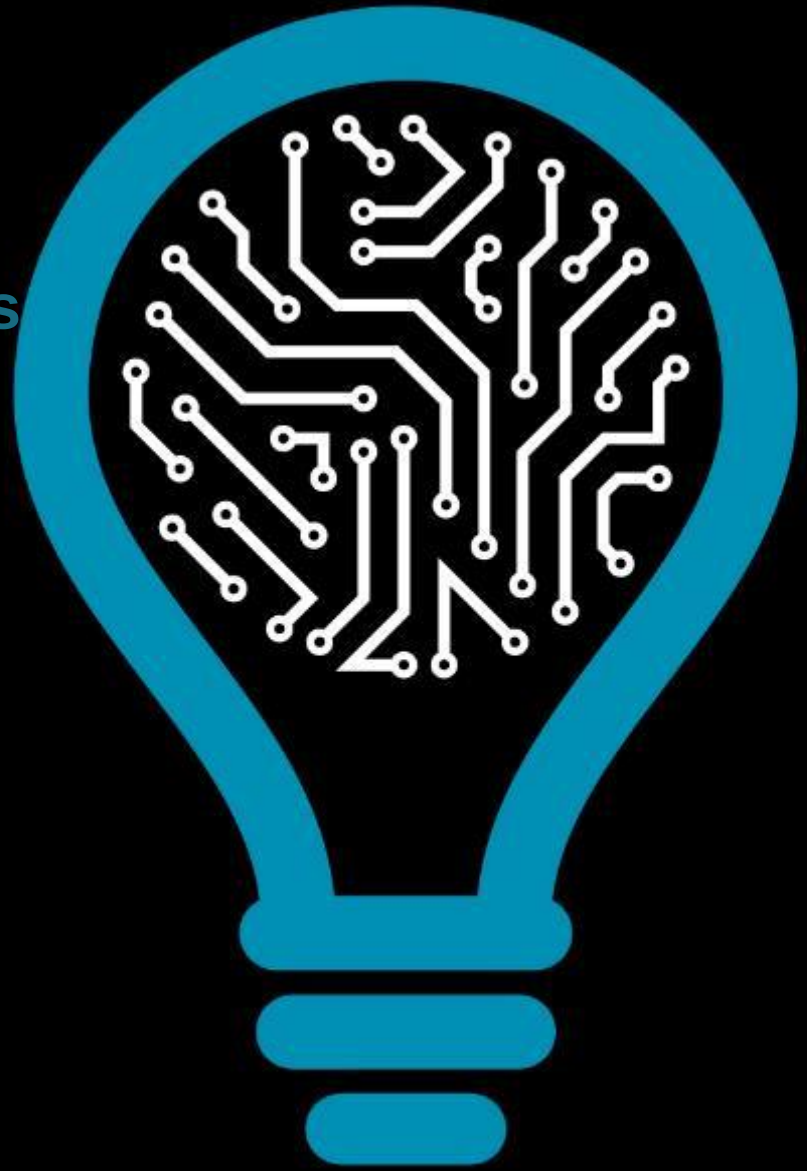
UAV-Assisted Wireless Communications: An Experimental Analysis of A2G and G2A Channels



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Scop and Motivation

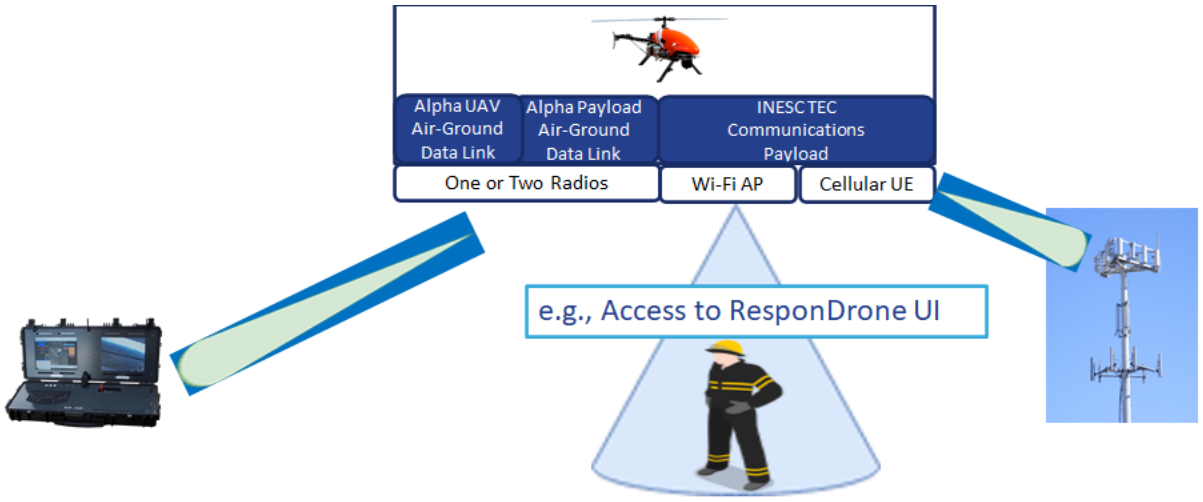
UAVs have evolved into versatile platforms for various applications

Integration of UAVs into wireless networks (emergency scenarios)

Optimize wireless links for non-critical critical data transmission

Challenges in establishing reliable broadband wireless links

ResponDrone



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Problem Characterisation and Proposed Concept

- **An open environment with no obstacles nor interference**
- **Considering the distance between UAV and the UE**
- **Considering the heading of UAV**

Main Contributions

Provides an experimental characterization of the Air-to-Ground (A2G) and Ground-to-Air (G2A) wireless channels

Analysing…

- **Received Signal Strength Indicator (RSSI) and the TCP throughput between a ground user and a UAV, covering distances between 50 m and 500 m, and considering different UAV headings**
- **characterize the antenna's radiation pattern based on UAV headings**
- **The Internet throughput, considering the distance**

System Setup

- The ATLAS site -> the location for the experimental measurements.
- One UAV -> Alpha 800 and carries a payload

- **2x APU 4D4 + 1x APU 3E4 backup**
  - CPU: 4x 1GHz x64
  - RAM: 4GB
- Wi-Fi Interface (Mikrotik R11E- 2HPND)
  - 802.11n @ 2.4 GHz
  - Capable of: MIMO 2x2 -> UE
  - Two omni-directional 2.4 GHz antennas with a gain of 5dBi are horizontally mounted in the front of the UAV
  - Up to 30 dBm
  - Ethernet: 4x 1 Gbit/s
  - OS: OpenWRT 19.07.8
  - SSD: M.SATA 32GB (Logs)
  - SD: 16GB (OS + Configs)
  - Modem 4G: USB LTE Cat6 2CA
    - Virtual Ethernet over USB
    - Virtual Serial port for configuration

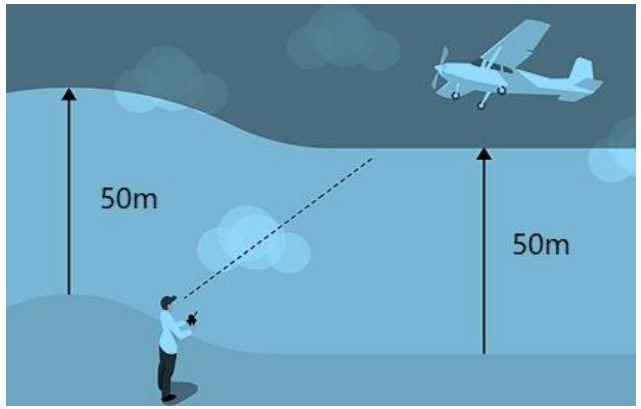
System Setup

- One UE -> A Xiaomi Mi 9T at 1.3 m above ground -> single antenna **MIMO -> better network performance**
- Between UAV and UE -> The IEEE 802.11n (Wi-Fi 4) standard, channel 1 with a bandwidth of 20 MHz
- Tx power of 20 dBm and 30 dBm for the UE and UAV
- Minstrel-HT -> Wi-Fi MAC auto-rate adaptation mechanism
- The UAV -> LTE by **two omni-directional triband antennas** vertically mounted in the rear of the communications payload
- The LTE BS is located 120 m away from the hangar
- BS -> Band 3 (1.8 GHz) -> theoretical throughput values up to 150 Mbit/s
- The real throughput measured in the UAV at a distance of 100 m from the LTE BS averaged 114 Mbit/s for downlink and 55 Mbit/s for uplink
- FAP – iperf 3 server
- UE – iperf 3 client, TCP **download**

Field Trial

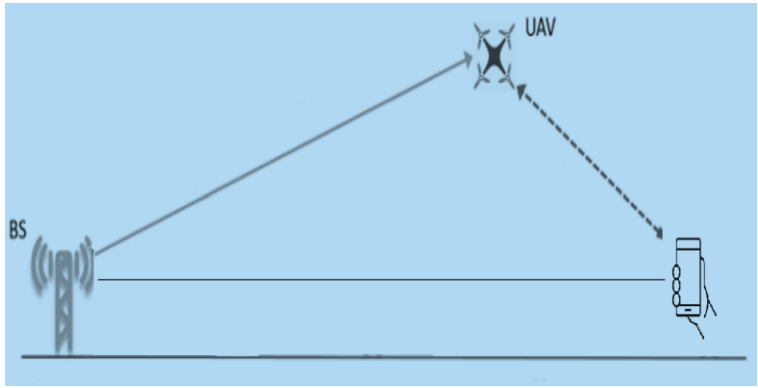
Scenario A: RSSI and Throughput *vs.* UAV heading

- Rotating the drone in 45º steps, 206m away from the UE (Euclidean distance), 50m altitude



Scenario B: RSSI and Throughput *vs.* Distance

- Moving the UAV away from the UE in 25m steps, 50m altitude, heading of 180º
- Coming back the UAV towardthe UE, 25m steps, 50m altitude, heading of 0º



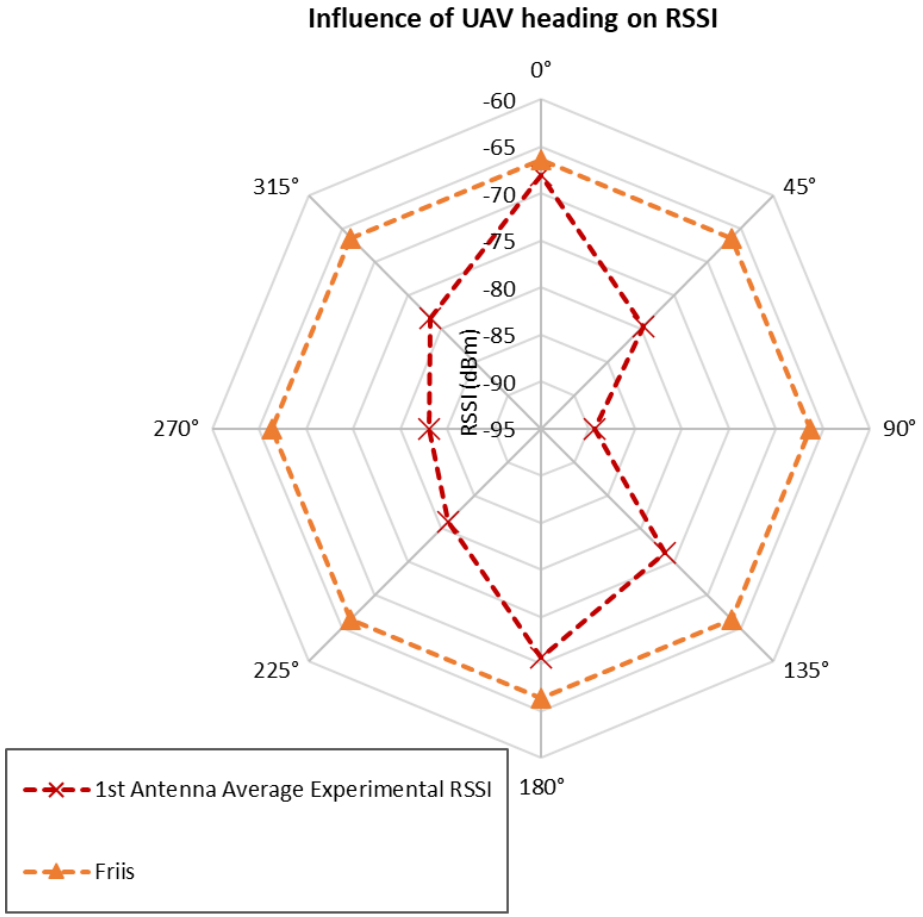
Scenario C: Internet Throughput vs LoS

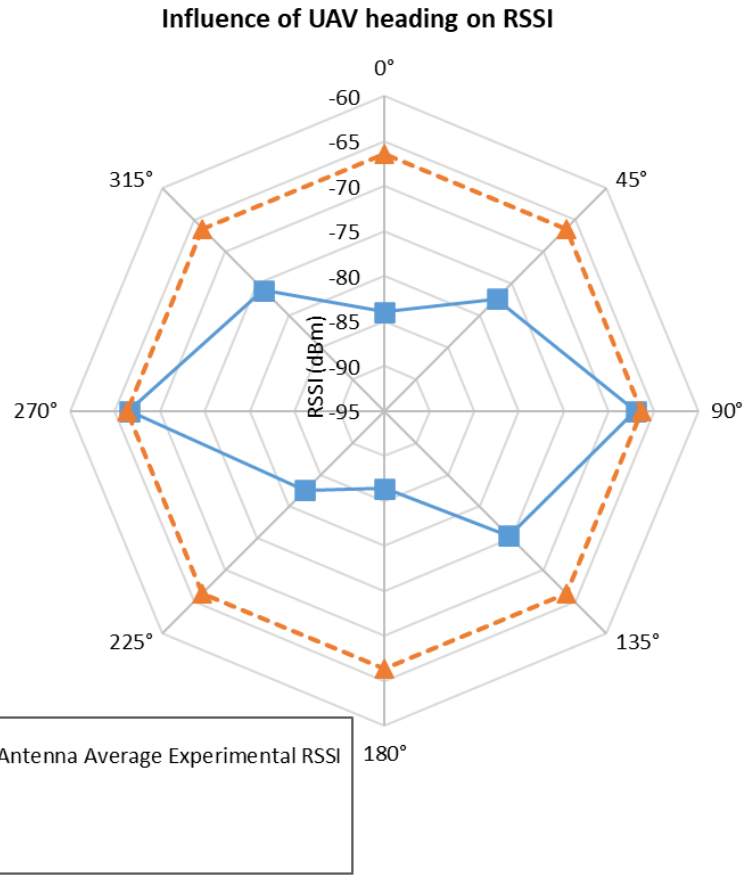
- The UE was located 1.42 km from the LTE BS
- The UAV was between the UE and the LTE BS (1.2 km away from the LTE BS and 220 m away from the UE)

Results

Scenario A: RSSI and Throughput *vs.* UAV heading

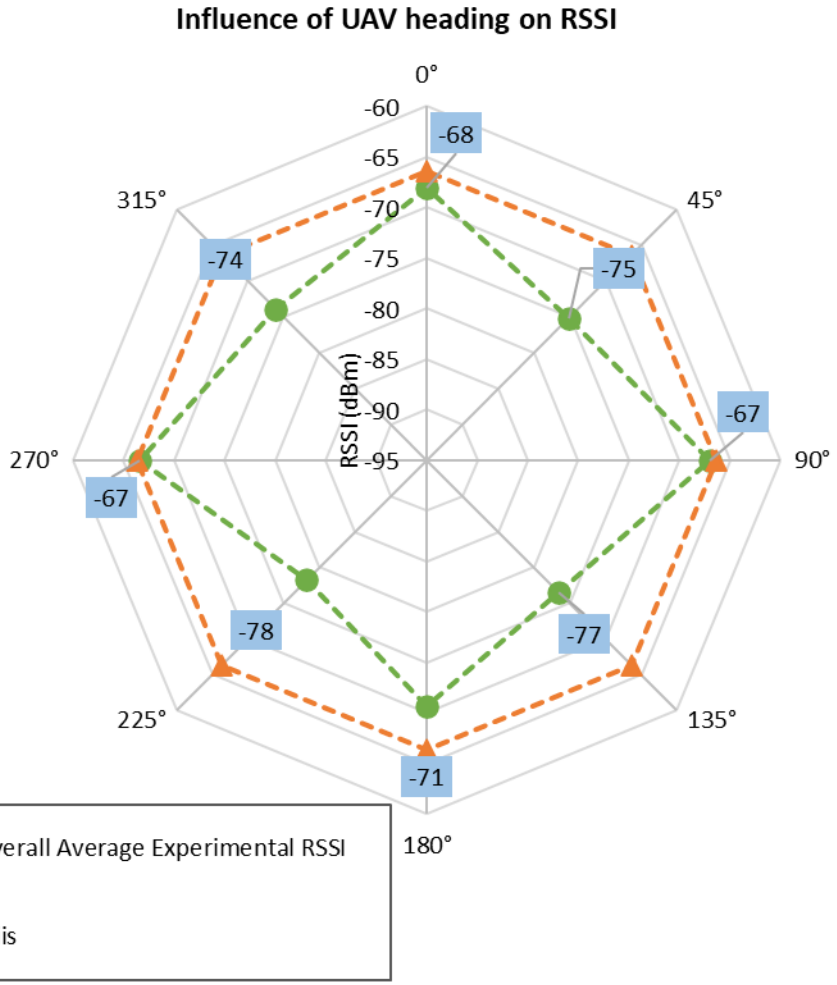
- **206m away from the UE, 50m altitude above ground level**: Measured RSSI of the packets received at both UAV antennas, depending on the relative heading between the UAV and the UE at a Euclidean distance of 206 m, compared to **Friis radiation pattern** with an isotropic antenna.

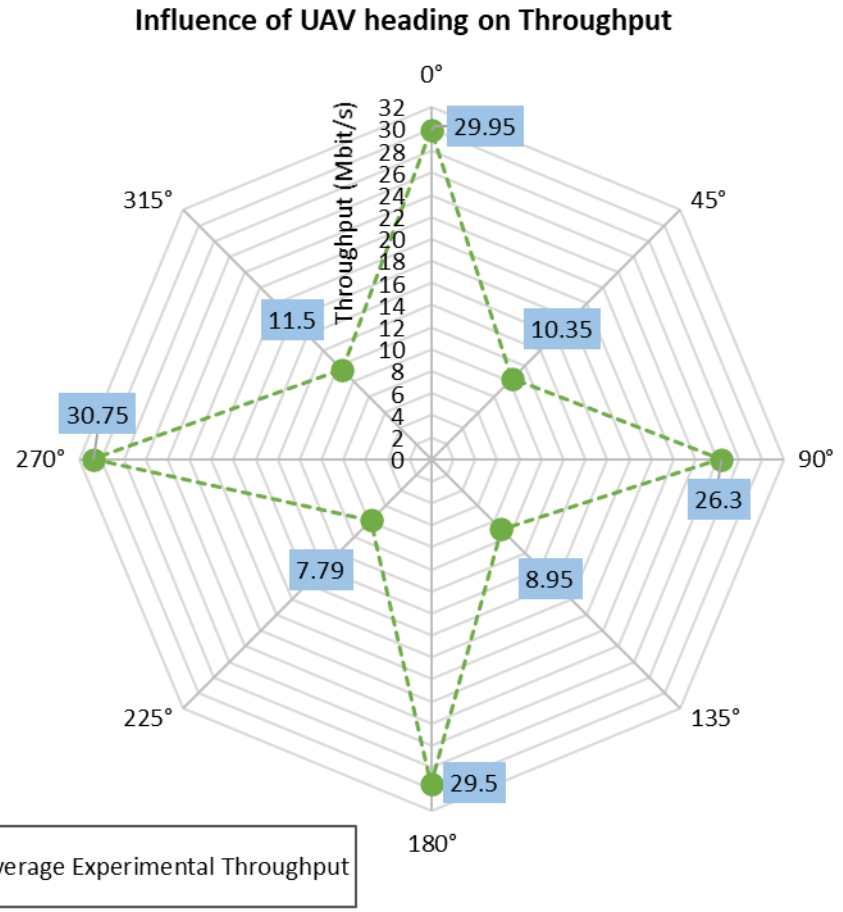




Results

Scenario A: RSSI and Throughput *vs.* UAV heading

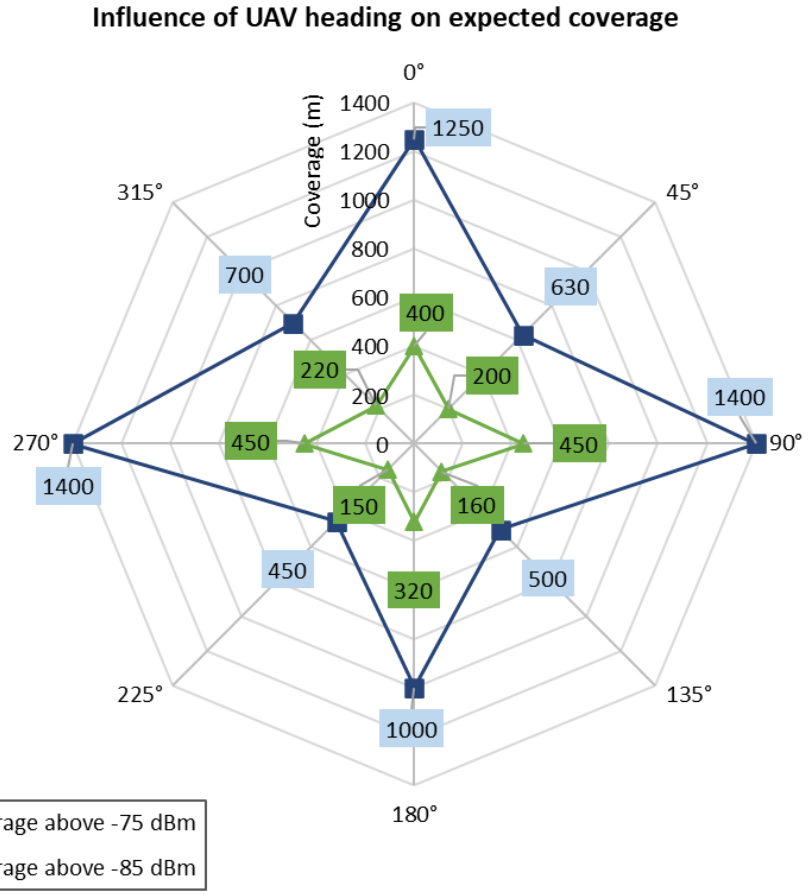




Results

Scenario A: Resulting expected coverage

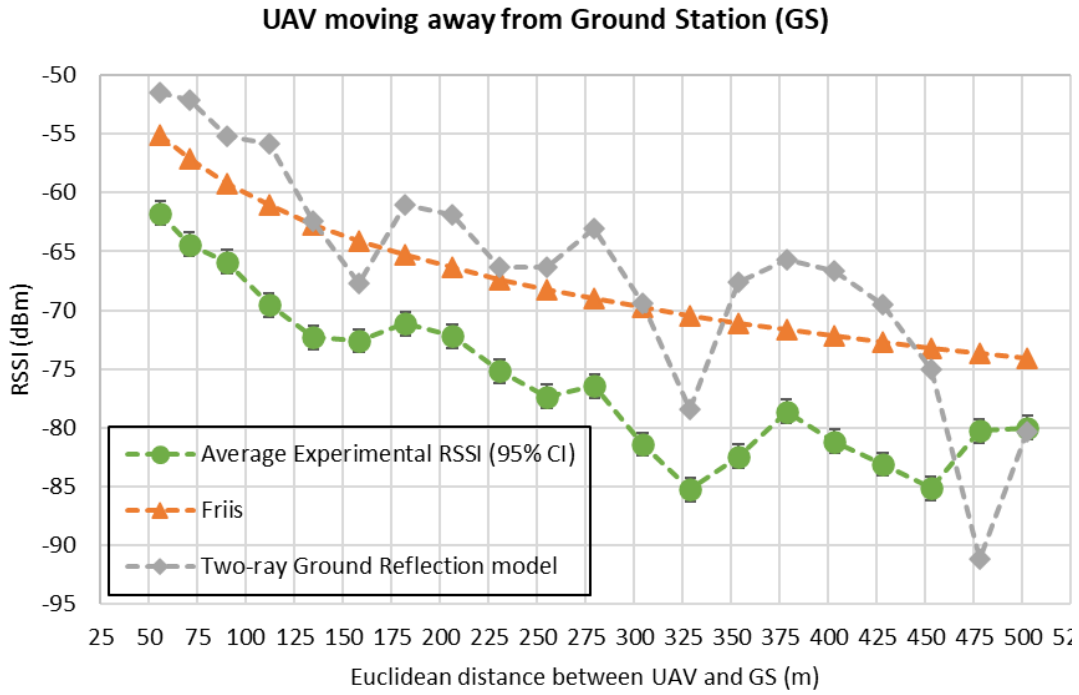
- -85 dBm link still stable with a SNR of 10 dB, but with low throughput.
- -75 dBm link with 20 dB of SNR, which still provides good performance for multiple video streams

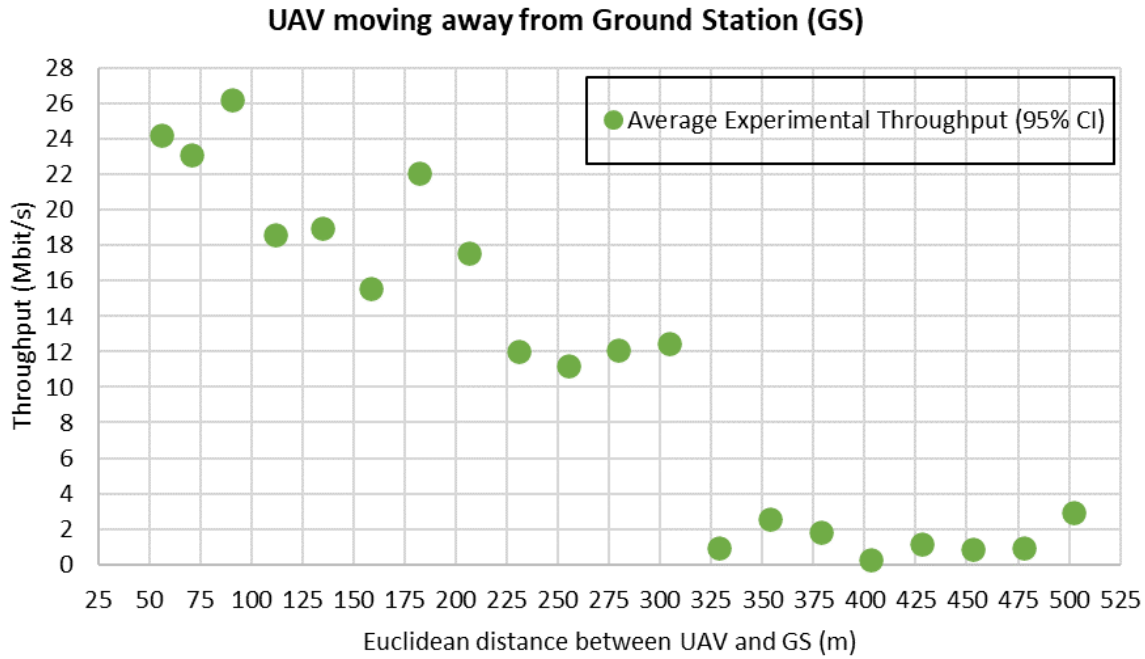


Results

Scenario B: RSSI and Throughput vs. Distance (moving away)

Experimental RSSI measured on the UAV compared to the Friis and Two-ray ground baselines and the downlink throughput measurements on the UE.



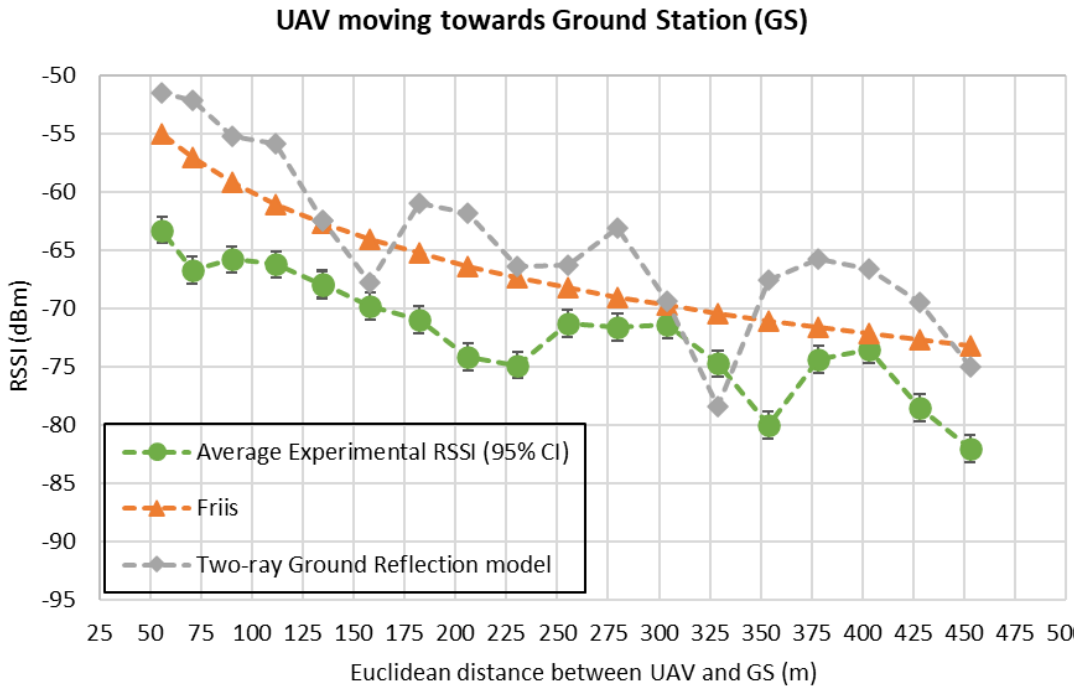


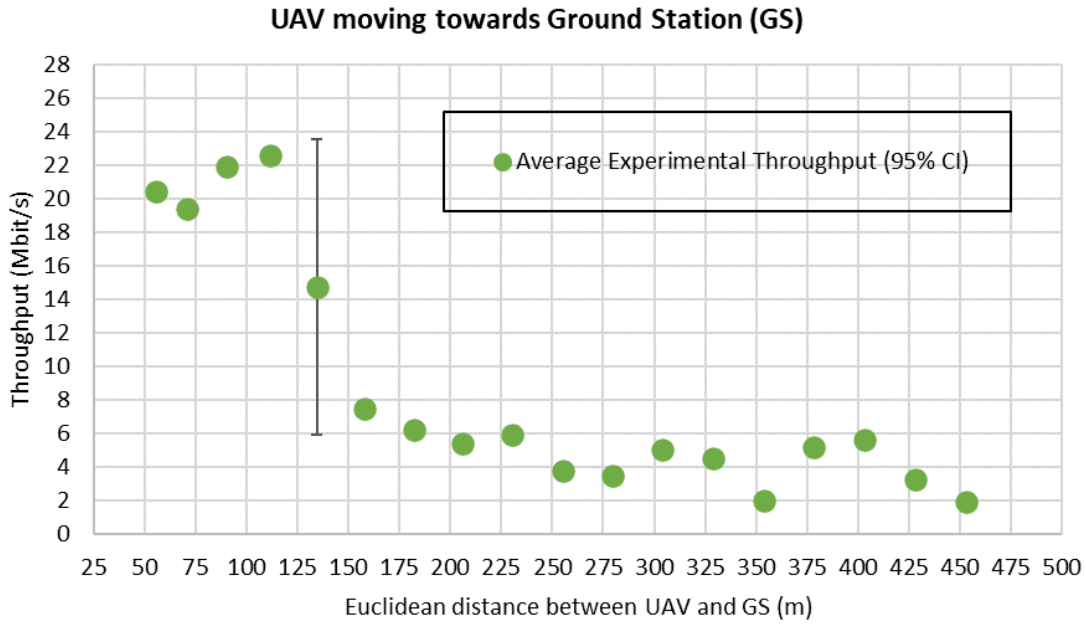
UAV moving away from UE in steps of 25 m, while maintaining a flight at 50 m AGL

Results

Scenario B: RSSI and Throughput vs. Distance (coming back)

Experimental RSSI measured on the UAV compared to the Friis and Two-ray ground baselines and the downlink throughput measurements on the UE.





UAV comes back towards the UE, repeating the same waypoints as before.

Results

Scenario c: Internet Throughput vs LoS

Distance of the UE to the LTE BS at the hangar. The UE was connected to the Internet either directly via LTE or via Wi-Fi through the UAV, which is then connected to the LTE BS.

- UE connected directly to the LTE BS, it achieved an average of 13 Mbit/s
- UE connected to UAV by Wi-Fi, it reached an average of 21 Mbit/s at the same location
- Gain of 1.6x

Conclusions

- accurate experimental model that describes the A2G and G2A channels
- Impact of the UAV's body and heading on RSSI and throughput
- importance of optimizing antenna design for UAV communications systems
- Minstrel-HT limitation

Future works

- Optimizing antenna designs for UAV communications systems and different UE antenna configurations
- To enhance rate adaptation mechanisms such as Minstrel-HT to better handle rapidly changing link conditions and address the degradation caused by the Fast-ACK mechanism in asymmetric links

Thank You

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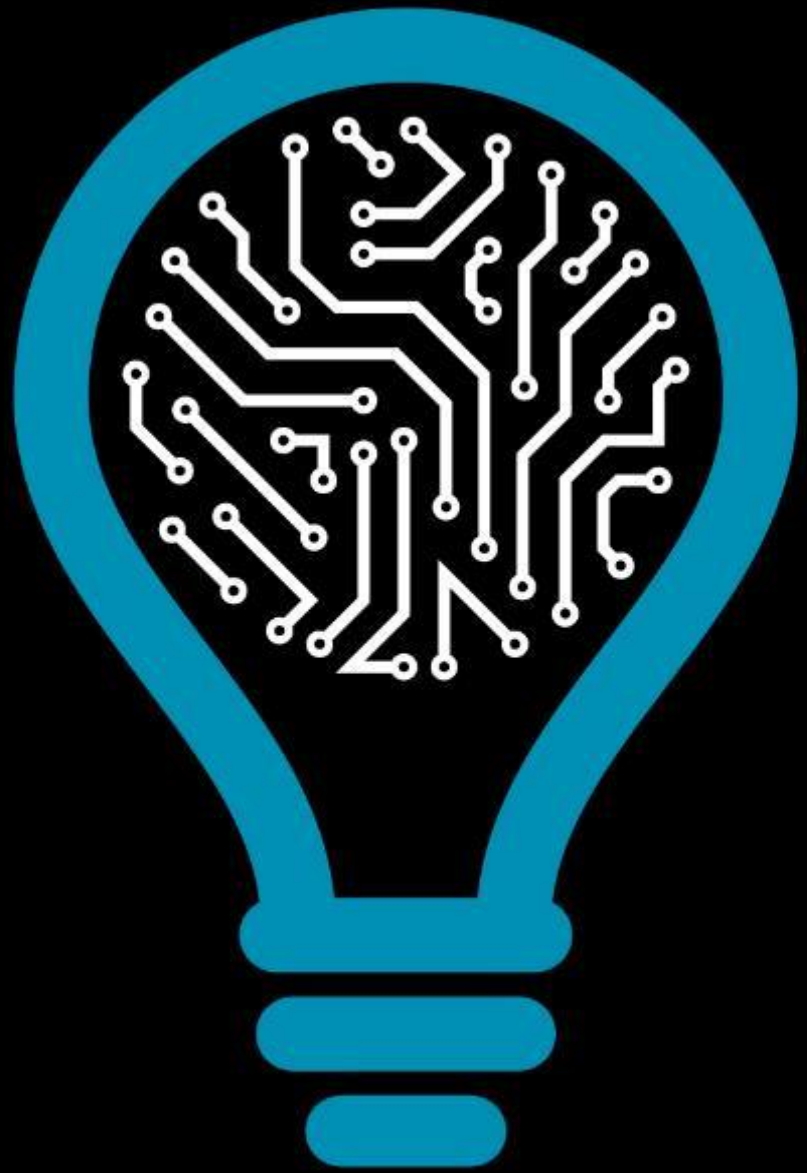

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