Poster: Data Collection from Outdoor IoT 802.15.4 Sensor Networks using Unmanned Aerial Systems

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CCS CONCEPTS

• **Networks** → **Network measurement**; *Network experimentation*; *Local area networks*; • **Computer systems organization** → **Sensor networks**; • **Applied computing** → *Environmental sciences*; *Agriculture*.

KEYWORDS

Internet of Things, 802.15.4, UAS, UAV, Drone, Sensor Network, Wireless Networks, Aerial networks, Experimental Measurements

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1 INTRODUCTION

Unmanned Aircraft Systems (UAS) are a promising technology for data collection from outdoor sensor networks. Environmental and agricultural networks may not have existing internet backhauls for data delivery due to low population densities in rural areas, making UASs a potential data delivery alternative. UASs can be deployed as aerial network relay nodes [4, 12, 14, 19] or as data mules [10, 15]. In addition to mending network fragmentation, UAS applications include post-disaster data collection involving inoperative communication infrastructure [1, 5, 6], supplementing existing communication infrastructure for vehicular networks [7], and rural applications in environmental monitoring [9, 18] and precision agriculture [8, 17].

While the performance of on-the-ground 802.15.4 networks is well understood [13, 16], communication in three dimensional space provides additional challenges. Compared to stationary or slow-moving ground-network nodes, UAVs are highly mobile, resulting in poor performance of protocols such as 802.11 [2]. Moreover, due to toroidal radiation patterns in consumer omni-directional antennas, antenna orientation can have a strong affect on signal quality in both 802.11 and 802.15.4 [3, 11].

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We present our current work on the use of 2.4GHz 802.15.4 for data collection from a UAS. Unlike past research, we examine ground-air interaction using a physical aerial test-bed, from a highly agile UAS in three dimensional space. We look at factors that affect UAS-based data collection as well as applications for UAS-based IoT network management.

2 OPTIMIZING GROUND-AIR DATA COLLECTION

Methodology: Our experimental data has been collected through the use of six Digi XBee3 RF 2.4GHz transceivers utilizing 802.15.4. Four XBee radios served as IoT transmitters, transmitting packets every 500ms, and were stationed in different experimental conditions: (1) flat on the ground; (2) on an edge on the ground; (3) mounted 0.5 meters above the ground; and (4) covered under one quart of debris. Our UAS, a DJI Matrice 100, was equipped with two XBees configured as receivers, one oriented parallel to the ground, the other perpendicular.

The UAS was flown in a straight line approximately over the transmitters at an average speed of five miles per hour. Each flight reached a total horizontal distance of 250-300m in both directions from the nearest transmitter and each trial was comprised of 13 altitudes: 30ft, 40ft, 50ft, 60ft, 70ft, 80ft, 90ft, 100ft, 150ft, 200ft, 250ft, 300ft, and 400ft.

Our current work comprises nine hours of collected data, totaling 121,503 received packets, including only the experimental portions of each flight. We reviewed the effects of altitude, antenna orientation, obstruction, and antenna elevation on RSSI and packet loss.

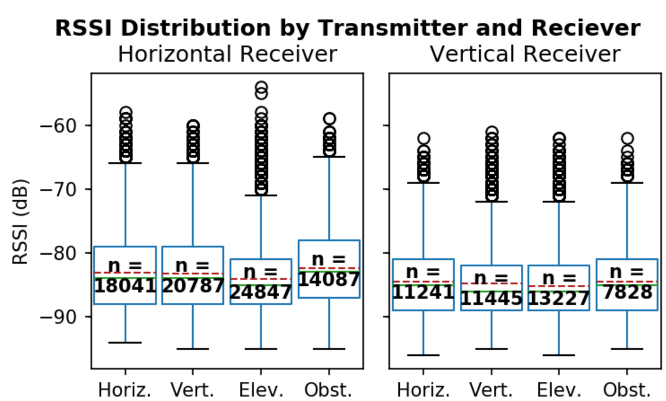

Figure 1: RSSI distributions by antenna configuration.

Performance Metrics: Our measurements show that aggregate RSSI is a poor indicator of overall network quality, whereas packet reception rate better reflects network performance. This is due to the lack of reception in regions with low RSSI. A lost packet should reflect negatively on the link quality, however, it has no affect on RSSI. This is represented in Figure 1, where all transceiver orientation combinations experience very similar RSSI metrics, but drastically different packet reception rates. Henceforth, RSSI lacks representation in regions with low connectivity and can be misleading in overall network quality.

Optimal Altitude: Although low altitudes generally improve packet reception and RSSI, higher altitudes provide better connectivity at greater horizontal displacements because they provide a steeper angle between the UAS and the transmitter, reducing signal blockage from obstacles such as trees and bushes. We find an altitude between 150ft and 250ft provides the best overall reception in our scenarios.

Transceiver Orientation: We find that *receiver* orientation noticeably impacts packet loss, while *transmitter* orientation has a negligible affect. In our results, the better performance of the parallel receiver could be due its superior line of sight, while the perpendicular receiver's own body may have blocked signal from unfavorable angles. Henceforth, we find that on-the-ground transmitter orientation can be selected without accounting for UAS collection, but in the event of aerial collection, the receiver should be oriented parallel to the ground.

3 IOT MANAGEMENT APPLICATIONS

Mapping IoT Deployments: After deploying sensors, network administrators may struggle to track device locations. We envision UASs as a way to automatically map and track changes to an outdoor IoT deployment. We are working on an RSSI-based system to automatically locate existing IoT devices from a UAS using 802.15.4.

Detecting Malfunctioning IoT Nodes: Our preliminary work finds that the performance of a transmitter obstructed by a quart of debris worsens by about 25%. By comparing passive network scans before and after a disaster, such as extreme weather events, a UAS-based system could automatically detect buried or inoperable sensors, aiding in recovery efforts.

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