Poster: MilliDrone: A Drone Platform to Facilitate Scalable Survey of Outdoor Millimeter-Wave Signal Propagation

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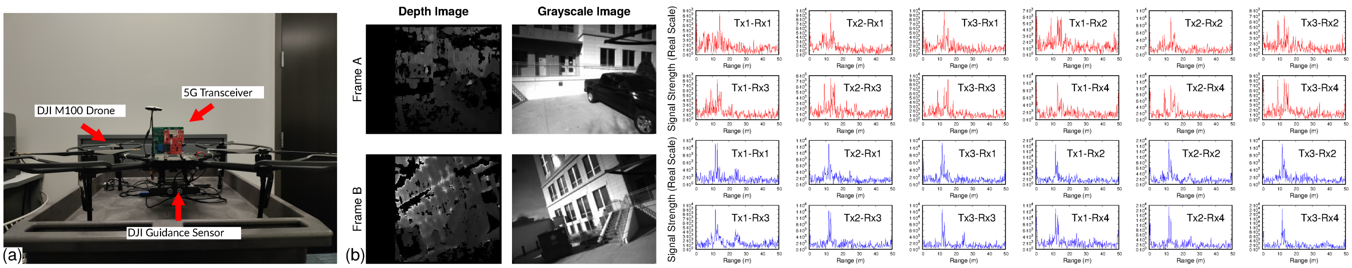

Figure 1: (a) *MilliDrone* platform with a mmWave transceiver mounted on a DJI Matrice 100 Drone. (b) Examples of in-flight data collected: Depth images; Greyscale images; mmWave reflections across 12 transmit-receive channels.

ABSTRACT

Millimeter-Wave (mmWave) networks rely on small, short-range base-stations called "picocells," which should be placed optimally to be effective. So, extensive surveying must be done in order to ensure there is no significant capacity loss. Existing approaches to conduct indoor surveying do not work outdoors due to many outdoor environmental factors. In this work, we propose *MilliDrone*, a Drone-based system equipped with a mmWave transceiver and a Guidance platform, and is synchronized to collect depth, greyscale, and mmWave reflection profiles by following a specified programmed path. Using the datasets, we intend to explore a machine-learning model to predict outdoor propagations, and in turn, predict the optimal outdoor picocell placements.

CCS CONCEPTS

• **Hardware** → **Sensor devices and platforms**; • **Networks** → **Network management**.

KEYWORDS

Drone, Millimeter-Wave, Picocell Deployment, Transceivers

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PROPAGATION SURVEY CHALLENGES

The increasing prevalence of 5G has raised the importance of optimally placed network infrastructures. 5G utilizes millimeter-wave (mmWave) as its core wireless technology, and it relies on small, short-range base-stations called "*picocells*," which are easily obstructed by environmental objects. Picocells can be placed on rooftops, utility poles, and other roadside infrastructures, but *they must be placed with careful planning, as even minor location changes can cause significant capacity loss*. So, identifying the optimal placement locations of these picocells requires extensive surveys.

While there exist approaches to conduct indoor surveys, they are ineffective outdoors due to variable factors, such as the height and number of buildings, traffic, pedestrians, area inaccessibility, *etc.* It is also expensive and cumbersome to manually survey large-scale outdoor environments. *To solve these issues and facilitate efficient outdoor picocell placement, we propose MilliDrone, a system comprising of a Drone equipped with a mmWave transceiver, optical cameras, and depth sensors* (Figure 1[a]). *MilliDrone* is especially useful when surveying areas with many tall buildings that often do not have the infrastructure for a traditional survey.

MILLIDRONE SYSTEM DESIGN

MilliDrone can be programmed to fly in any specific pattern while avoiding obstacles. The system comprises a 77 GHz mmWave transceiver mounted on a DJI Matrice 100 Drone and a Guidance System [1]. We use the onboard SDK to control the Drone's flying path and the Guidance SDK to capture both the RGB and Depth (RGB-D) images and odometry samples. The mmWave transceiver is equipped with 3 transmit and 4 receive antennas, enabling us to continuously measure reflection profiles from 12 virtual channels at any 3D pose.

However, a tight hardware-level synchronization between the Drone, Guidance System, and mmWave transceiver is currently unavailable. Nevertheless, the collected RGB-D images, Drone's poses, odometry samples, and mmWave reflections must be synchronized for correct data analysis. To this end, *MilliDrone* post-processes the data to facilitate a software-level synchronization by carefully considering the start and end times for each system and using the difference to offset the data. Still, the sampling rates between the systems may not match, and some may capture samples at irregular intervals (*e.g.*, the transceiver has 25 fps, but the depth imager has only 6 fps). To overcome these challenges, we use a combination of interpolation and decimation to match rates across systems; in practice, median decimation and piecewise cubic interpolation methods yield good results. We collected datasets across 4 outdoor environments, and Figure 1(b) shows the depth, greyscale, and mmWave reflection profiles from two poses in one environment. The reflection data also shows that the outdoor mmWave signals are highly sparse.

In the future, we plan to collect datasets from multiple, large-scale outdoor environments. Still, we may not be able to gather data from every *nook and cranny* of an environment due to the Drone's limited battery and area inaccessibility. We propose to explore a machine-learning model that exploits the correlation between visual data and mmWave reflections (similar to [2, 3]) to predict the outdoor propagations characteristics from any viewpoint, even if the Drone has not measured them. In addition, we plan to extend the Drone's field of view to 360° by mounting multiple mmWave transceivers and RGB-D cameras. Besides, we will investigate methods to calibrate the dataset by modeling Drone's vibration and removing potential spiking noise due to abrupt flight pattern change (for example, under a gust of wind).

ACKNOWLEDGEMENT

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