Mobility Patterns to Optimize Communication for Distributed Capture Processing Onboard Autonomous UAVs

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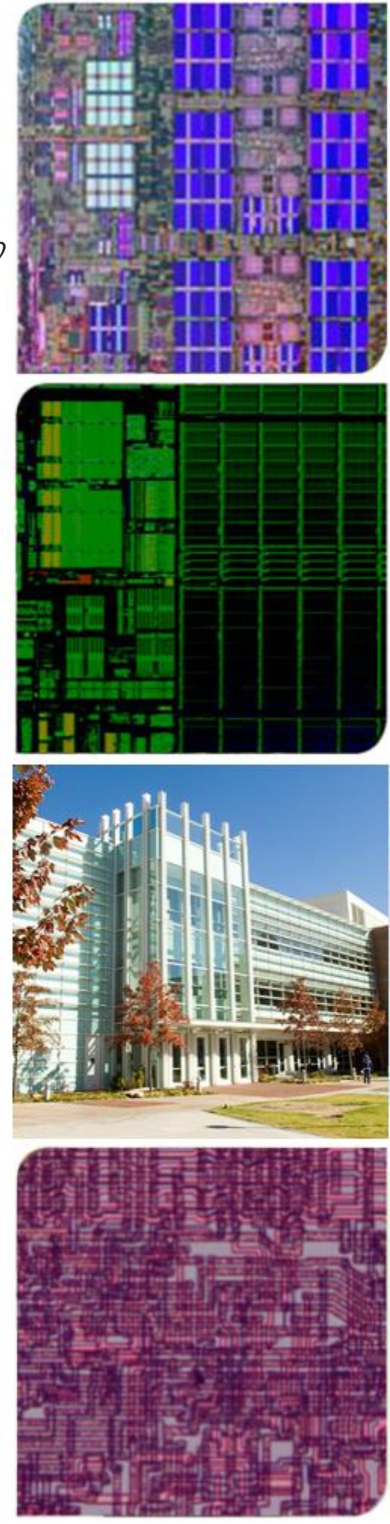
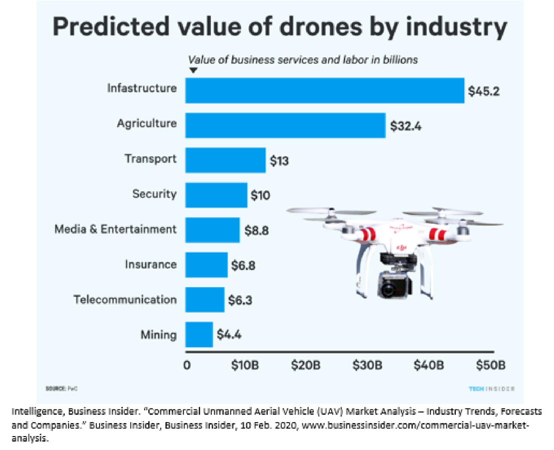


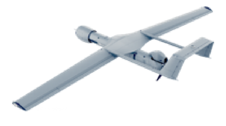
Motivation

- Commercial UAV industry will reach 805,000 in sales in 2021, a CAGR of 51%[1]
- Increasing use cases of UAVs from surveying land to emergency services and national security
- Communication between multiple UAV agents is increasingly becoming a bottleneck [2]
- Optimizing communication directly affects overall flight range and mission time
- Different physical form factors have different communication signatures



Draganfly M600 (Photo: Draganfly)

DJI Matrice (Photo: DJI)

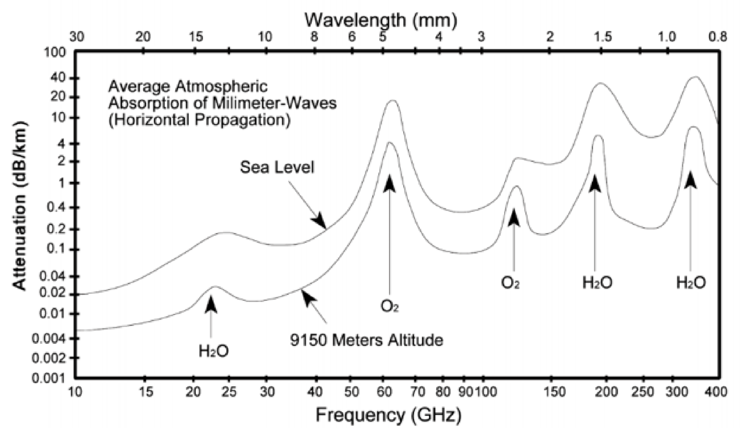


Orbital ScanEagle3 (Photo: Orbital)

MMCUAV Grifilon M8 VTOL (Photo: MMCUAV)

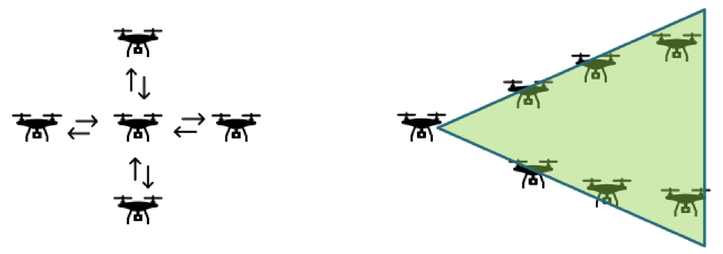
mmWave

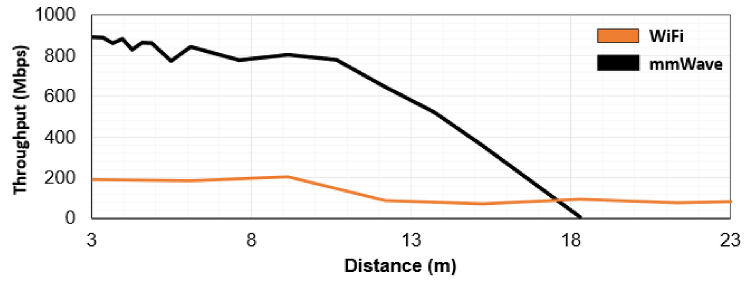
- Millimeter Wave (mmWave) spectrum between 30 GHz and 300 GHz
  - V band (60 GHz) set aside by FCC to be unlicensed
- High bandwidth
- Limited by short range
  - Due to oxygen absorption[6]
- *Bandwidth vs. Data Rate*
  - $C = B\ \log_2(1+\frac{S}{N})$ [Shannon-Hartley Theorem]
  - Channel Capacity (C) is increased w/ higher bandwidth (B) keeping signal-to-noise ratio constant.



Utilizing mmWave for UAVs

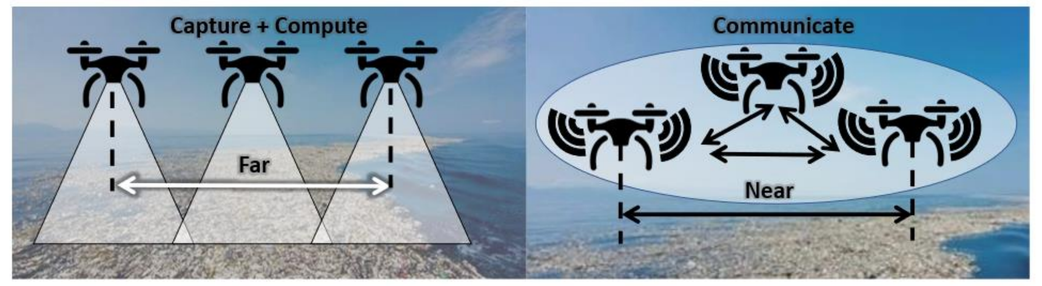
- Two utility configurations
  - Star config
  - Cone config
- Two modes of operation
  - Wi-Fi
  - mmWave
- Wi-Fi for long range low throughput
- mmWave for short range high throughput
- Dynamically switch between the two modes on-the-fly
- But when should it switch?

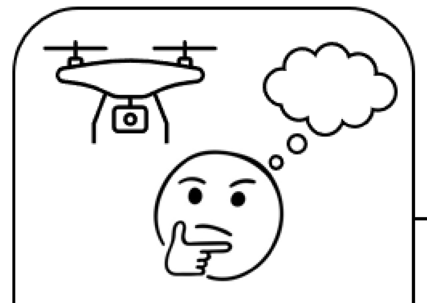




Envisioned Setting

- Large scale forest fire
  - Objective is to quickly 3D map areas with immediate threat to human life & property
  - 3D Map to be used for SAR
  - High signal attenuation, cannot use base station
  - Area of interest is too large for a single UAV
  - Limited backhaul links
- Can be extended to any situation where backhaul and cloud links are not feasible
  - Ocean rescue, oil spill mapping, missions in mountain ranges etc.





Making Location Schedule for Drones?

Should we get the **drones closer** and use **high bandwidth communication** while incurring the **movement penalty**?

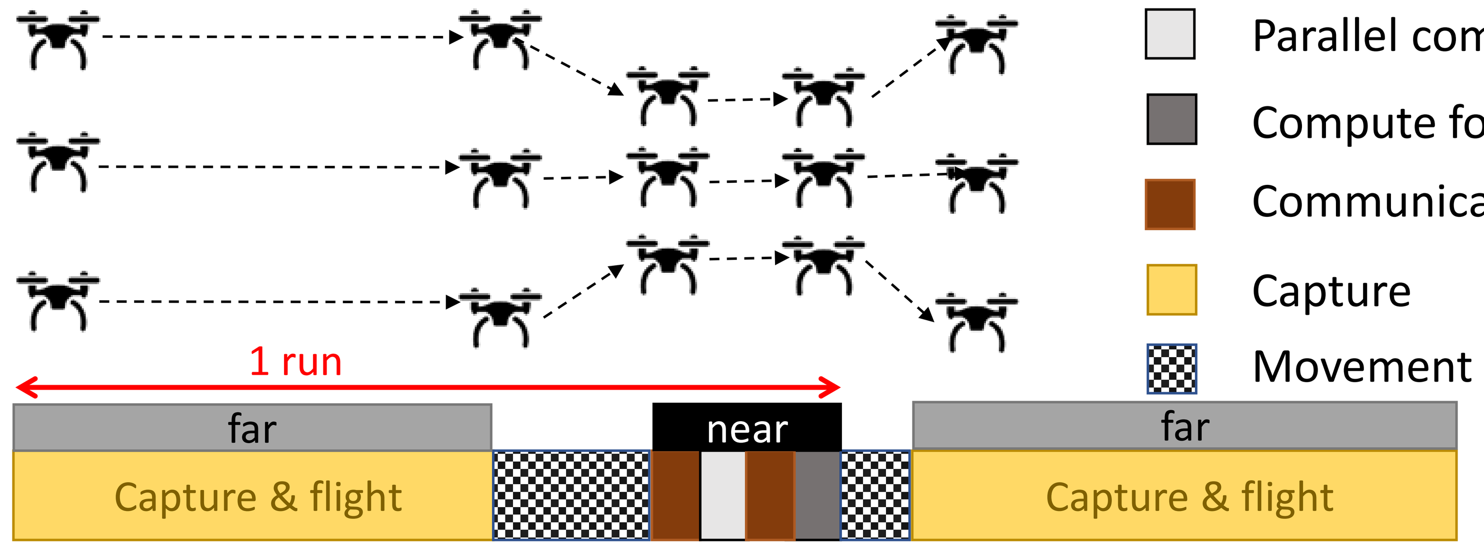
Or Should we keep the **drones at distance** and use **low bandwidth communication** while incurring the **bandwidth penalty**?

Understanding these tradeoffs and their characteristics are critical to solve the correct set of problems

Virtual-Machine Based Mission Simulation → Expected Ordered Trace

Physical Parameters (energy usage, data-rate) → Optimization Algorithm

Expected Ordered Trace → Optimization Algorithm → Location Schedule



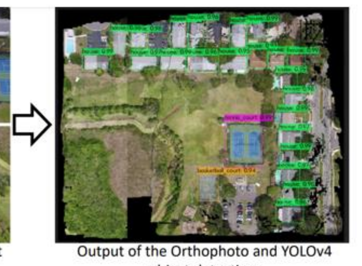
- Parallel compute
- Compute for next path
- Communicate
- Capture
- Movement (far - near)

Experiment Setup

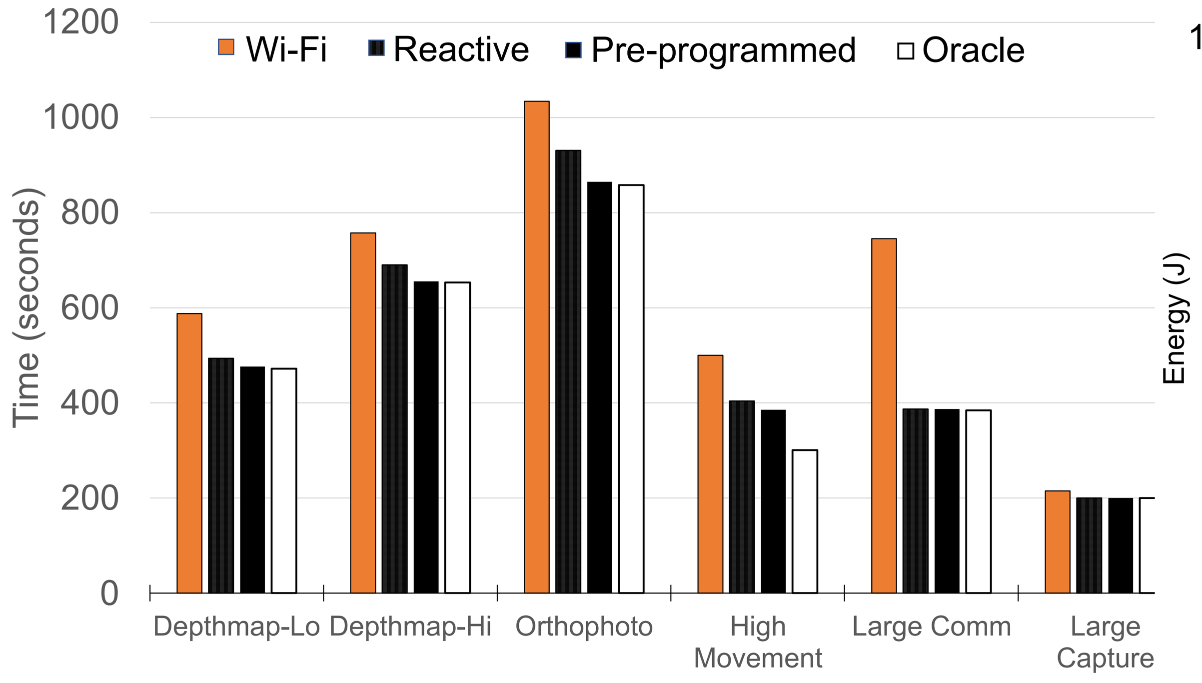
- Distributed CV Processing
  - Single node, Two/Four node Wi-Fi, Two/Four node mmWave
  - Compute model from Raspberry Pi 4 [7] and parameters configured
  - Parameters and knobs imported into VirtualBox[8] VMs
  - OpenDroneMap[4]
  - VMs configured for each run to simulate different mission characteristics
  - Network monitoring using Wireshark[5] and iperf3[3]

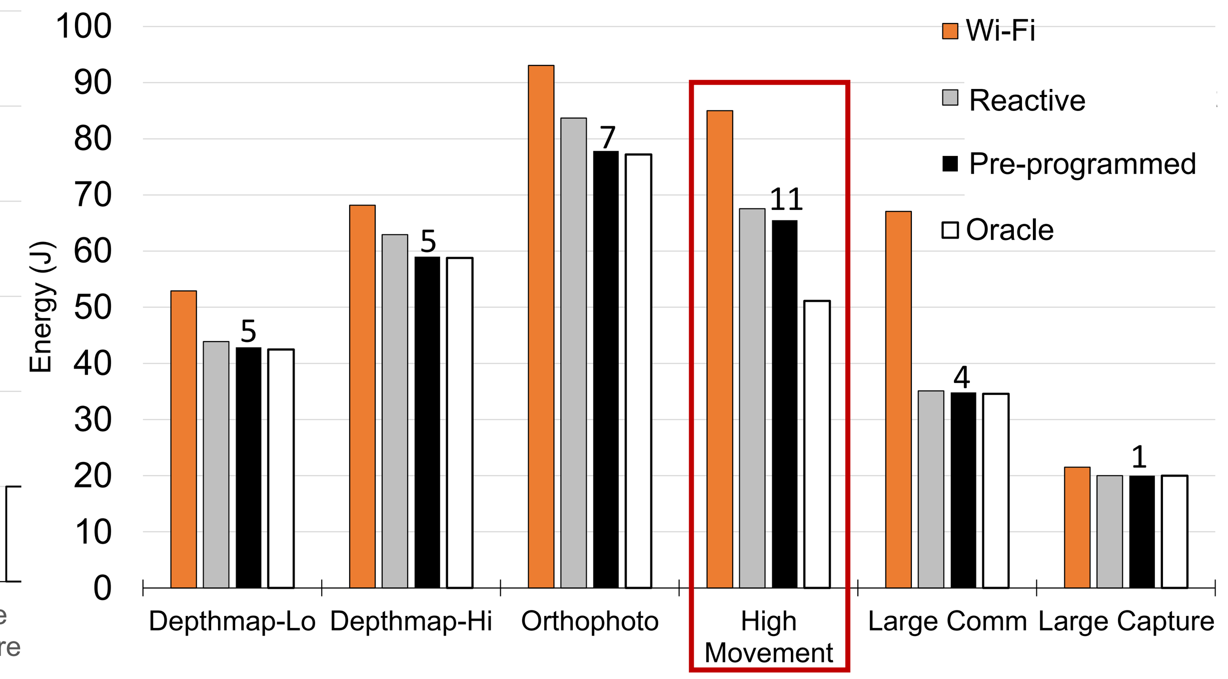
Feature Extraction (Photo: Seabee)

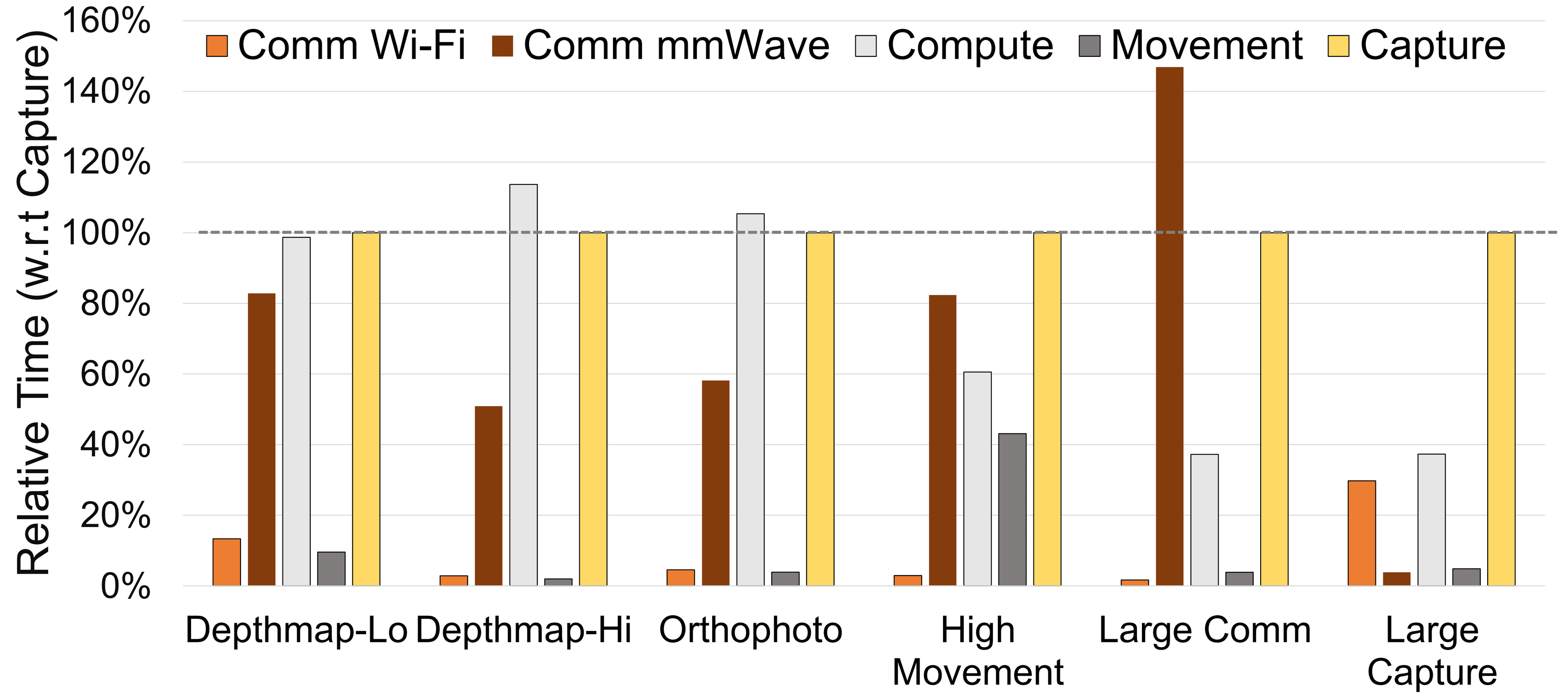
Sample input images captured from different angle by drones.

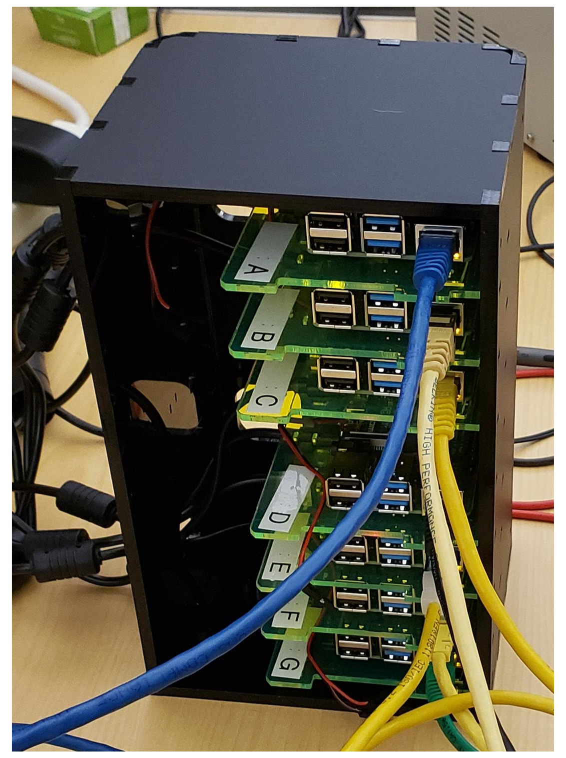


Output of the Orthophoto and YOLOv4 object detection.









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Key Contributions & Future Directions

- The key contributions of our work as summarized
  - A novel approach to run distributed algorithms on autonomous agents where control of proximity improves efficiency.
  - A movement scheduling algorithm that incorporates goals of compute, communicate, and capture of data.
  - Example use-cases that demonstrate the proposed scheduling algorithm's benefits to various distributed application scenarios.
- Future Directions
  - End-to-end System Implementation
  - Variations in Compute Tasks
  - Real-time Decision making
  - Scalability analysis