Trajectory-Based Cyber-Physical Networks (TCN): Theoretical Foundation and a Practical Implementation

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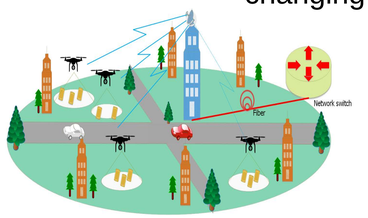
Introduction

TCNs such as Unmanned Aerial Vehicles (UAVs) changing our lives



Aerial base stations

Package delivery

Agriculture

Surveillance

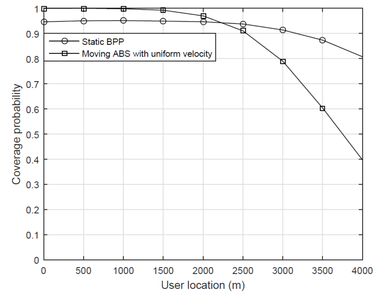
- UAVs move along **non-deterministic paths (trajectories)**
- Trajectory-Based Cyber-Physical Networks (TCN) is **interdisciplinary**, employs techniques:
  - Probability
  - Stochastic geometry
  - Wireless networks
- **Challenge:** there is no rigorous probabilistic theory that can effectively capture trade-offs between wireless communications, transportation measures, and application measures

Broader Impact

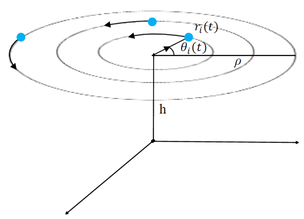
The proposed project has the potential to improve understanding, modeling, and design of several emerging real-life systems, especially UAS.

Design of Mobile Aerial Base Stations(ABS) Networks Using Trajectory Process Theory

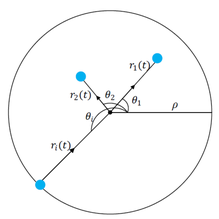
- **Stochastic geometry analysis** has already been applied to a network of **fixed ABSs**
  - BPP distribution for ABSs can provide fairly uniform coverage
- **Benefit of Mobile ABSs:**
  - Reduction in energy consumption
  - Reduction in average fade duration (AFD)
  - Other applications(such as package delivery) need mobility
- **Coverage probability:** *ABSs start their flight with **constant speed** and **uniform angle** can provide uniform coverage*?



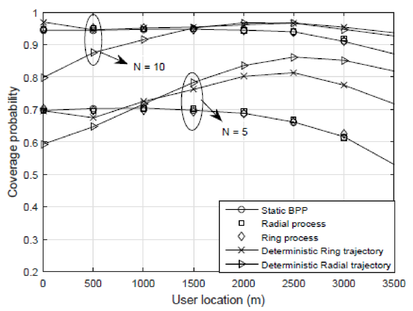
Trajectory process



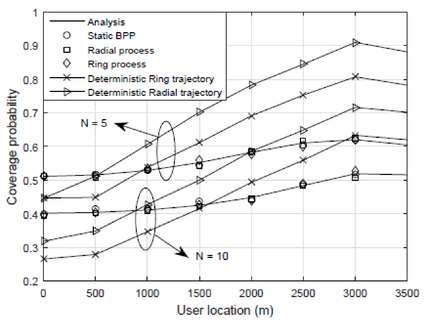
Ring trajectory process



Radial trajectory process



Network without interference



Network with interference

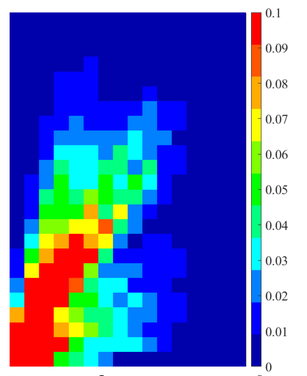
Design of Multi-Purpose UAVs

- **Last-mile delivery**
  - goal is to minimize the overall delivery time

$$\eta = \frac{T_m^*}{T_m(A)}, 0 \le \eta \le 1$$

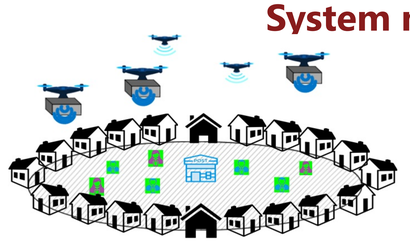
- **Deployment in communications(ABS) and surveillance**
  - common requirement is providing uniform coverage
    - ❖ percentage of the time each region is covered by drones over time
- Drones are used as **last-mile delivery** tolls *can provide uniform coverage, simultaneously*?

University of Massachusetts (UMASS) campus



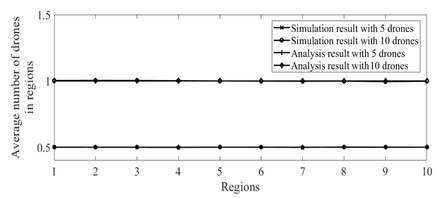
Heat-map of average number of drones

System models



Ideal case

Practical case



Average number of the drones ove the regions for 5 and 10 drones

	Efficiency	fraction of packages (average) with delivery time >30 mins
UMASS Community	1	0.006
Union point Community	0.87	0.012