Master's research plan seminar

UAV Trajectories Design for Emergency and Disaster Management Network

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2024 Dec 5th

Outline

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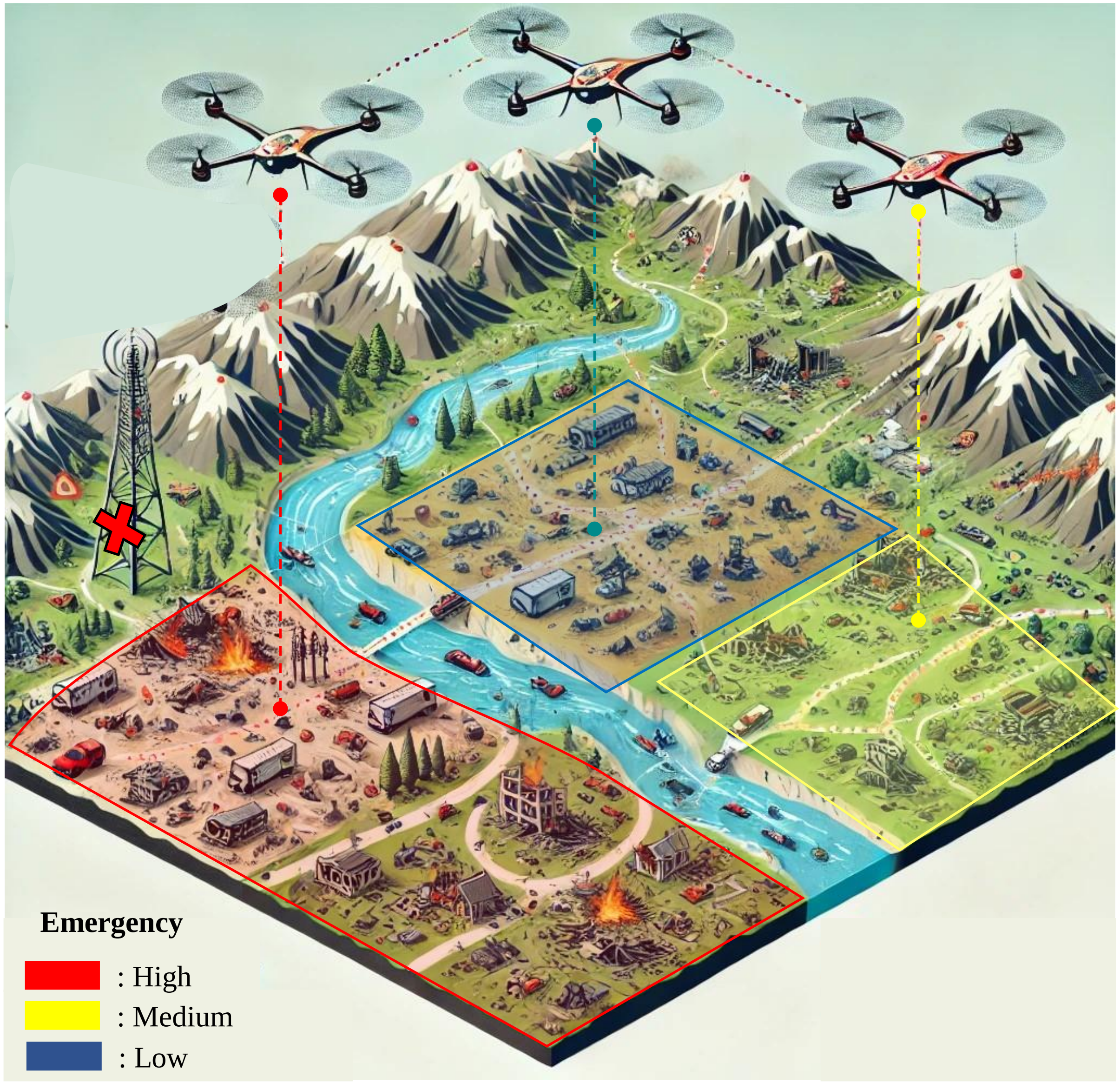
1.1 Motivation: Enhancing Emergency Connectivity with UAVs

- **Disaster impact communication:** Network infrastructure damage in emergencies leaves affected populations offline, hindering communication and service access.
- **Role of UAVs:** Unmanned aerial vehicles (UAVs) functions as temporary aerial base stations, quickly restoring connectivity in disaster zones.
- **Optimizing UAV Trajectories:** Effective UAV trajectory design is crucial, prioritizing high-risk areas and adjusting based on emergency severity.




1.2 Goal: UAV Trajectory Design



Emergency Network: Various Emergency Levels

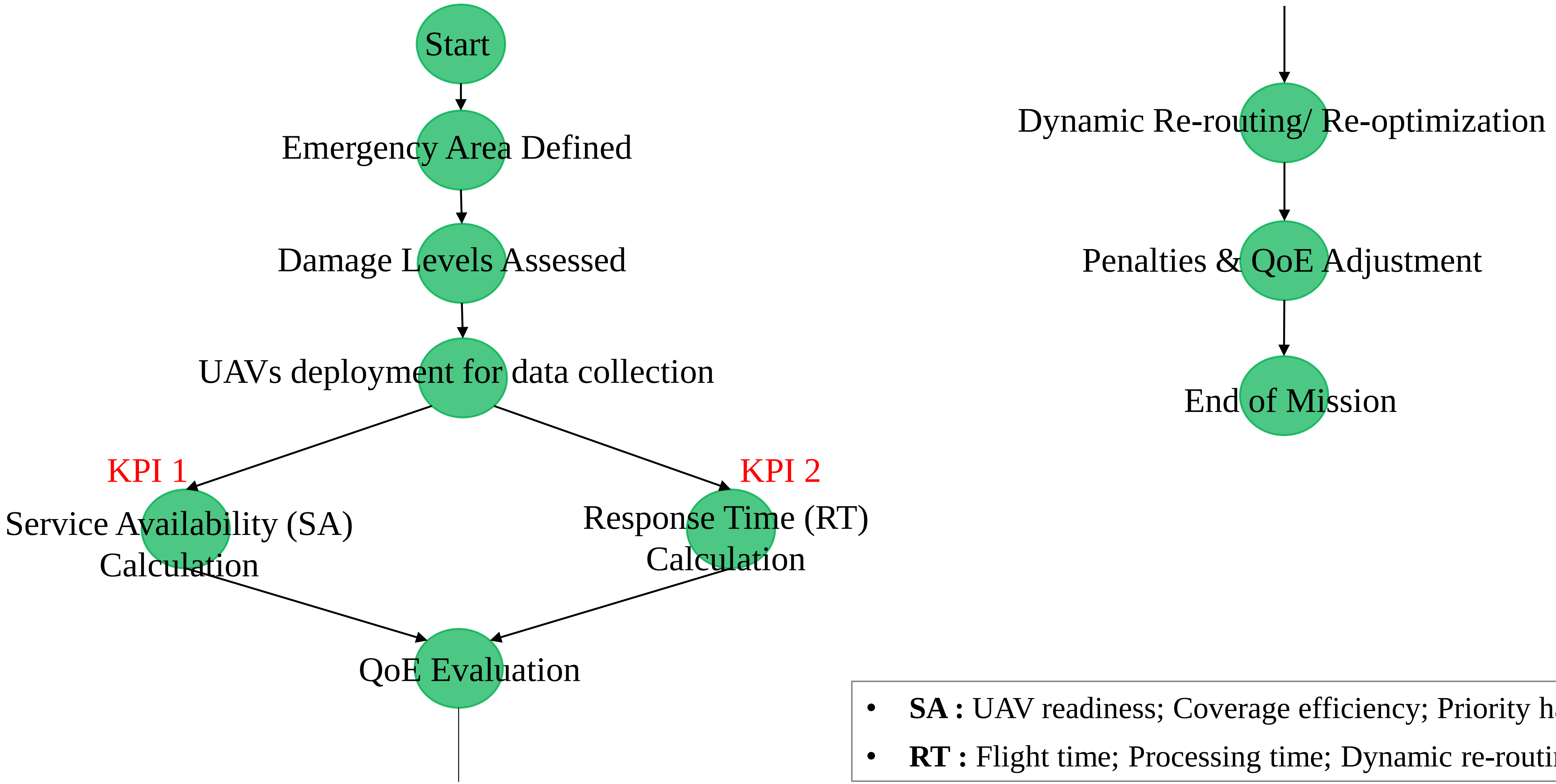
UAVs have limited coverage and we should have a proper trajectory design. Therefore, they can serve the network effectively.

We consider:

- Emergency response network
- Real-time trajectory optimization
- Cooperative multi-UAV operations
- Adaptability to emergency severity
- Performance evaluation using QoE metrics

1.3 QoE-Based Performance Metrics for UAV Trajectory Design

Flowchart:



- **SA :** UAV readiness; Coverage efficiency; Priority handling.
- **RT :** Flight time; Processing time; Dynamic re-routing.

1.4 Customized Emergency Level Indicators: Adjustable

Total score ranges for categorizing the disaster:

- **Low** Emergency (Level 1): **Score 0-5**
- **Moderate** Emergency (Level 2): **Score 6-10**
- **High** Emergency (Level 3): **Score 11-15**

Indicator No.	Indicator Name	Score Range
1	Infrastructure Damage	0 - 3
2	Population Impact	0 - 3
3	Disaster Severity	0 - 3
4	Urgency of Response	0 - 3
5	Environmental Complexity	0 - 3

Score	Description	Indicator 1 – Scoring Description (Infrastructure Damage)	Indicator 2	Indicator 3	Indicator 4	Indicator 5
0	Minimal or No Damage	Communication networks are fully operational or only minor disruptions. UAVs may not be necessary.	xx	xx	xx	xx
1	Partial Disruption	Some infrastructure is damaged (e.g., isolated outages or partial network loss). UAVs may need to cover a small region for supplementary communication	xx	xx	xx	xx
2	Significant Damage	Large-scale damage to communication networks (e.g., some neighborhoods or towns are cut off). UAVs need to cover wider areas and assist in restoring communication.	xx	xx	xx	xx
3	Total Infrastructure Failure	Complete loss of communication infrastructure. UAVs are essential for large-scale network restoration across the entire disaster zone.	xx	xx	xx	xx

2. Existing Solutions: Trajectory Optimization for Emergency Network

Reference	Summary
[2] 2022-3 [3]-2023-4 [4] 2024-6	**Static Environment-Based:** The studies focus on scenarios where the environment and user locations remain unchanged over time. These scenarios typically involve simpler conditions, where UAVs are deployed in predefined settings such as with minimal emergency dynamic factors.
[1] 2021-9 [5] 2024-4	**Dynamic Environment-Based:** The studies present a more complex scenario where the UAVs need to adapt to changing conditions, such as obstacles and user distribution, and the need for real-time adjustments during emergency. These environments require continuous UAV re-routing, energy-efficient strategies. → These papers address dynamic UAV trajectory optimization but do not consider varying emergency severities.
Challenges	• **Single UAV Focus:** While few studies consider multiple UAVs, most solutions focus on a single UAV, which might not scale for large-scale or more complex emergency areas. • **Fixed UAV Characteristics:** UAVs operate at a constant altitude and speed, with limited adjustments based on environmental factors. • **Simplified Obstacles and Environmental Factors:** Limited consideration of real-time changes such as user mobility or dynamic obstacles. • **Varying Emergency Scenarios:** None of above papers address varying emergency severities, which could be essential for adapting UAV behavior based on disaster scale and urgency

➡ **UAV trajectories design adapted to varying emergency severities has not been addressed.**

3. Research Proposal

(1) Addressing Dynamic Environments in Emergency Scenarios.

- Adaptable responses based on real-time changes in emergency severity.
- Prioritizing high-risk areas with dynamic flight path adjustments.

(2) Addressing Cooperative Multi-Agent UAV Trajectory Design.

- Coordination of UAVs through machine learning for optimal path planning.
- Real-time cooperation and adjustments to ensure rapid responses.

(3) Performance Evaluation Using QoE Metrics.

- Measuring UAV network effectiveness through KPIs: Service Availability (SA) and Response Time (RT).
- Analyzing performance to improve decision-making and UAV deployment strategies.

4. Approaches

This research aims to improve UAV-assisted communication systems for disaster scenarios by addressing

(1) Dynamic Environments in Emergency Scenarios,
(2) Cooperative Multi-Agent UAV Trajectory Design,
(3) Performance Evaluation Using QoE Metrics.

The goal of this research is to develop a novel cooperative UAV trajectory design using multi-agent machine learning, with a focus on prioritizing emergency levels.

A QoE framework is proposed, incorporating two main KPIs.

Service Availability (SA): 60%

- **UAV readiness:** Battery levels, health status…
- **Coverage efficiency:** The area the UAVs can cover.
- **Priority handling:** UAVs respond to different levels of emergency priorities.

Response Time (RT): 40%

- **Flight time:** Time taken to reach the emergency site.
- **Processing time:** Time for UAV to analyze data and act.
- **Dynamic re-routing:** how fast the UAV can change its path when needed.

5. Expected Contributions

1. Design adaptive UAV trajectories for emergency networks, leveraging machine learning to optimize flight paths based on dynamic emergency levels.
2. Introduce a flexible framework for UAVs to efficiently prioritize emergency zones and adjust their paths in real-time.
3. Evaluate the proposed design using Quality of Experience (QoE) metrics to assess its effectiveness in emergency scenarios.
4. Provide actionable insights and practical design guidelines based on the evaluation results, enabling better decision-making for real-world deployment of UAV-based emergency networks.

6. Research Timeline

Q3 2024
Literature Review

Q4 2024
Study machine learning (focus on DRL)

Q1-Q2 2025
Formulate the problems and implement the DRL algorithm

Q3-Q4 2025
Evaluate the system performance

Q1 2026
Write the thesis

Q2 2026
Thesis submission

Thank You.

Technology isn't just a breakthrough; it's a tool to adapt and protect lives.

References

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2. D. -H. Tran, V. -D. Nguyen, S. Chatzinotas, T. X. Vu and B. Ottersten, "UAV Relay-Assisted Emergency Communications in IoT Networks: Resource Allocation and Trajectory Optimization," in IEEE Transactions on Wireless Communications, vol. 21, no. 3, pp. 1621-1637, March 2022.

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5. Y. Guan, S. Zou, H. Peng, W. Ni, Y. Sun and H. Gao, "Cooperative UAV Trajectory Design for Disaster Area Emergency Communications: A Multiagent PPO Method," in IEEE Internet of Things Journal, vol. 11, no. 5, pp. 8848-8859, 1 March1, 2024.