Geometry-Based Optimization Heuristics for Region Coverage and Pathfinding in Drone-Based Operations

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Problem Solving

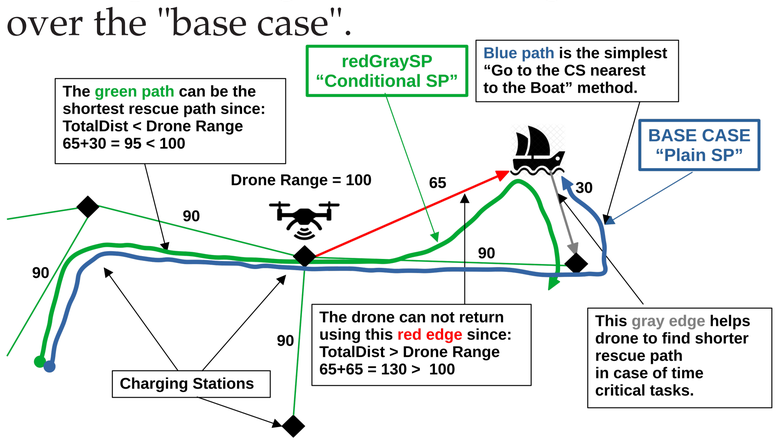
Drones are versatile and can be used as mobile IoT platforms. However, the limited onboard energy requires optimization to increase operational effectiveness.

Static Operation: Region coverage is vital for communication in case of natural disasters or temporal events.

We proposed multi-objective priority based heuristic optimization based on EAs that can approximates solution quickly to overcome complex formulation (for optimization) and "$\mathcal{NP}$-Hardness".

Dynamic Operation: Rescue operations requires "region coverage" with CSs for the operational range of the drones. The "optimum" rescue path should be found quickly.

We proposed optimum (min number) and "no-blind spot" CS grid to cover the operation region. The CS grid not only increases the operational range of the drone but also creates synergy with the proposed heuristic pathfinding algorithm, redGraySP, which "saves path length" in the range of 10-17% over the "base case".



Heuristic idea used for redGraySP.

Contributions

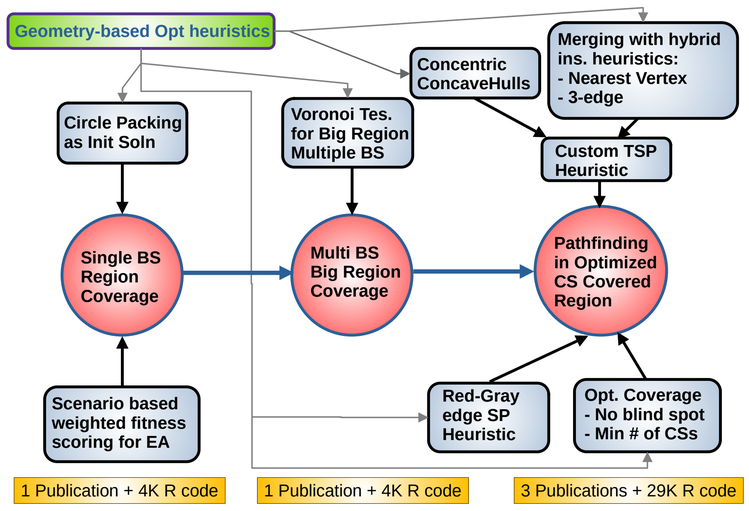
Region Coverage

- Novel and essential objectives for the coverage: **Overflow, overlap, sum of drone distances (energy).**
- Performance improvement: **Circle Packing** algorithm for the initial solutions to EAs.
- **Scenario based weighted scoring** for the fitness function.
- **Multi BS** coverage framework for **Voronoi Tessellated region**, utilization of homogeneous/heterogeneous BSs.

Pathfinding

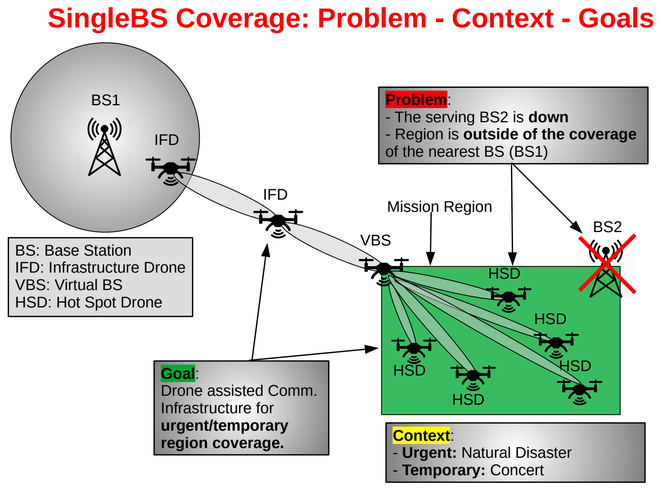
- **Static optimal (min CS - no blind spot) CS Grid** adjusted to drone range for complete region coverage.
- Novel **Coverage Effectiveness** metric for CS Grid.
- **Custom TSP + redGraySP pathfinding heuristics**.

Research Summary

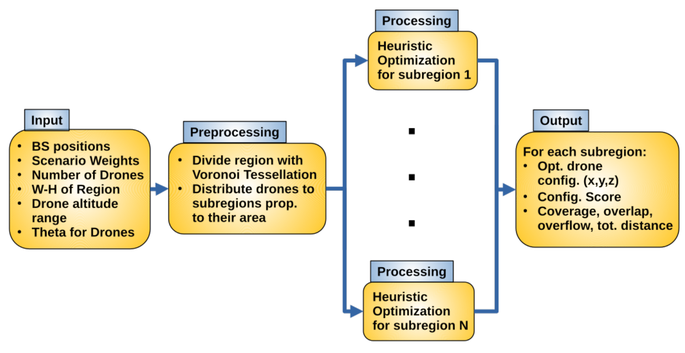


We proposed a flexible Evolutionary Algorithm (EA) based multi-objective multi-party optimization scheme for **single/multi-BS disaster region communication coverage** (first and second row) and a framework for **optimized heuristic drone pathfinding over an optimized charging station grid** for "visiting" entities in a "covered region" (bottom row).

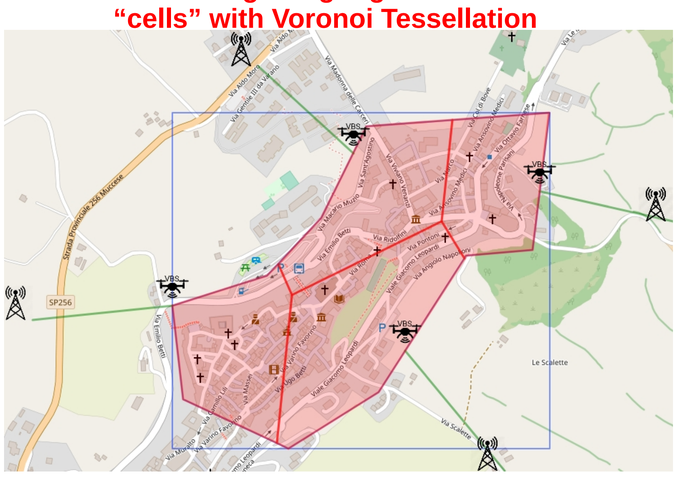
SingleBS Coverage: Problem - Context - Goals



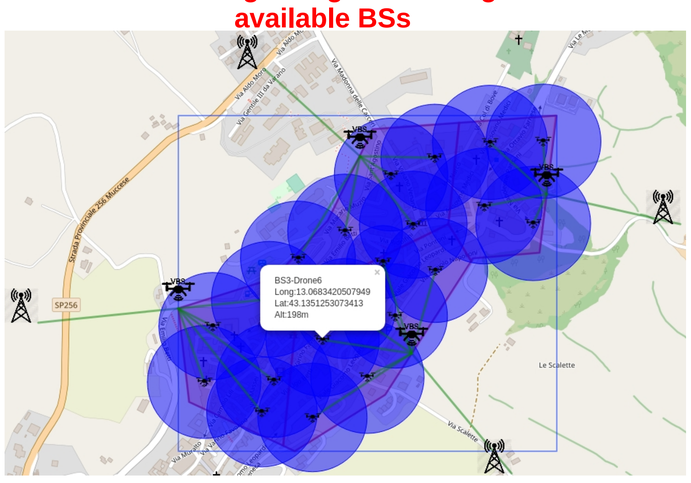
MultiBS Coverage: Process Flowchart



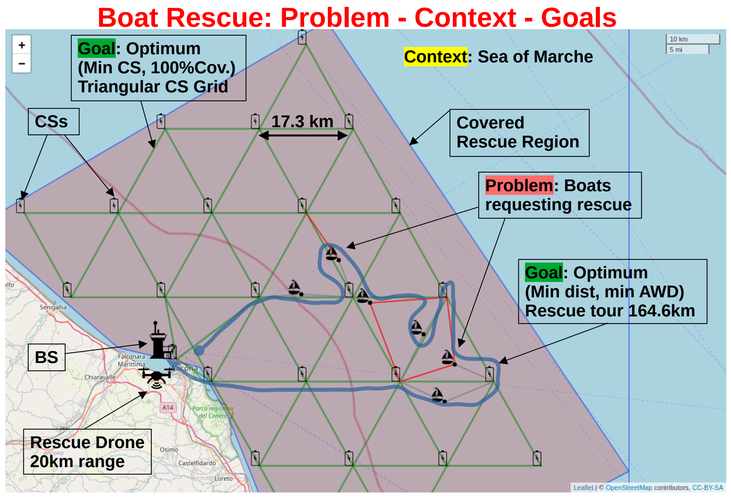
MultiBS Coverage: Big region divided into 4 "cells" with Voronoi Tessellation



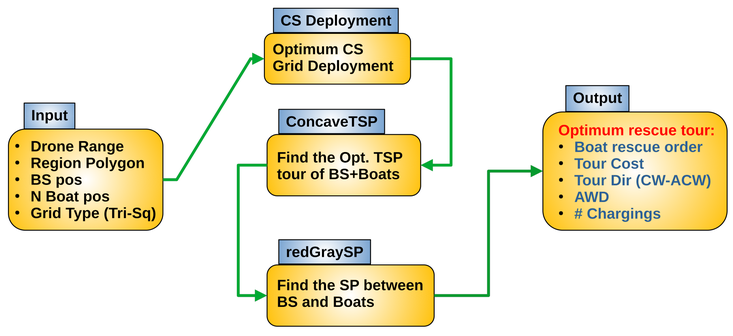
MultiBS Coverage: Region coverage with 4 available BSs



Boat Rescue: Problem - Context - Goals



Boat Rescue: Process Flowchart



References

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[2] K. I. Kilic, O. Gemikonakli, and L. Mostarda. Voronoi Tesselation-based load-balanced multi-objective priority-based heuristic optimisation for multi-cell region coverage with UAVs. Int. Journal of Web and Grid Services, 17(2):152–178, 2021.

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