Simulating Multi-hop Communications in a Swarm of UAVs

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Overview

- **Unmanned Aerial Vehicles (UAVs)**
  - Target Search Problem with Multi-hop
- **Testbed System**
  - Icosystem Swarm Game
  - Structure
- **Implementation**
  - Communication Range
  - Single-Source Shortest Path
- **Results**
  - Targets Discovered
  - Effect of Communication Ranges
- **Conclusions**
- **Future Work**

- Can be almost airplane-size or small, like a remote-control toy
- Small UAVs have advantage
  - Reach spaces too small for humans
  - Sneak into an area unnoticed
- If small, can't complete mission with just one, and each needs pilot
  - Minimize human resources with swarms
- Emergent behavior present in swarms – how to control?

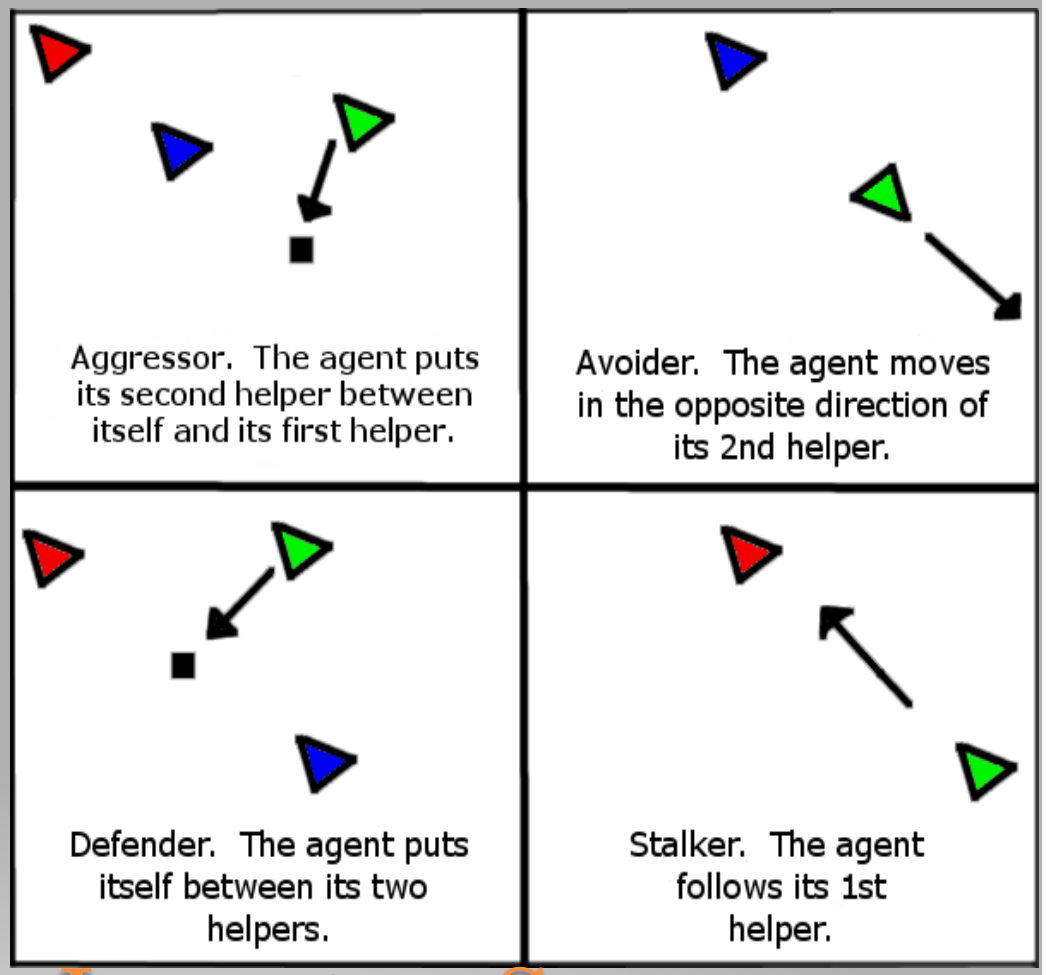
Unmanned Aerial Vehicles (UAVs)

Target Search Problem with Multi-hop

- Target search
  - Targets with unknown locations placed randomly
  - UAVs must find as many as possible
- Multi-hop
  - Communication system with limited range
  - Range extended by picking best UAV to “hop” to next
    - Other UAV sends message on to next hop until reach destination UAV
  - Agents perceive different snapshots of the UAV network
  - Need to optimize path taken to destination UAV
  - Investigate solutions to agent(s) straying
    - Straying here is falling out of range of all other UAVs

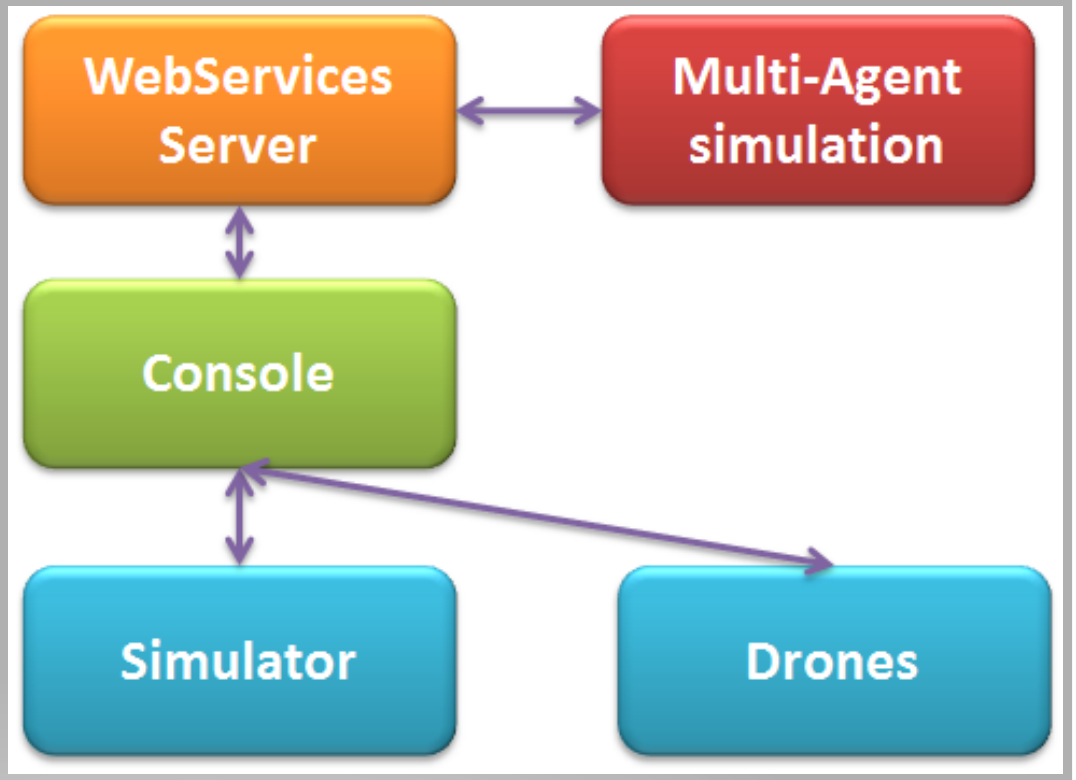
Testbed System - Icosystem Swarm Game

- Multi agent system, where individuals follow certain rules
- To control swarm movement, have a leader that becomes each agent's first helper
  - Only need to tell leader where to go and others follow
  - Use only aggressor and defender rules, because they have strong attachment to the first helper

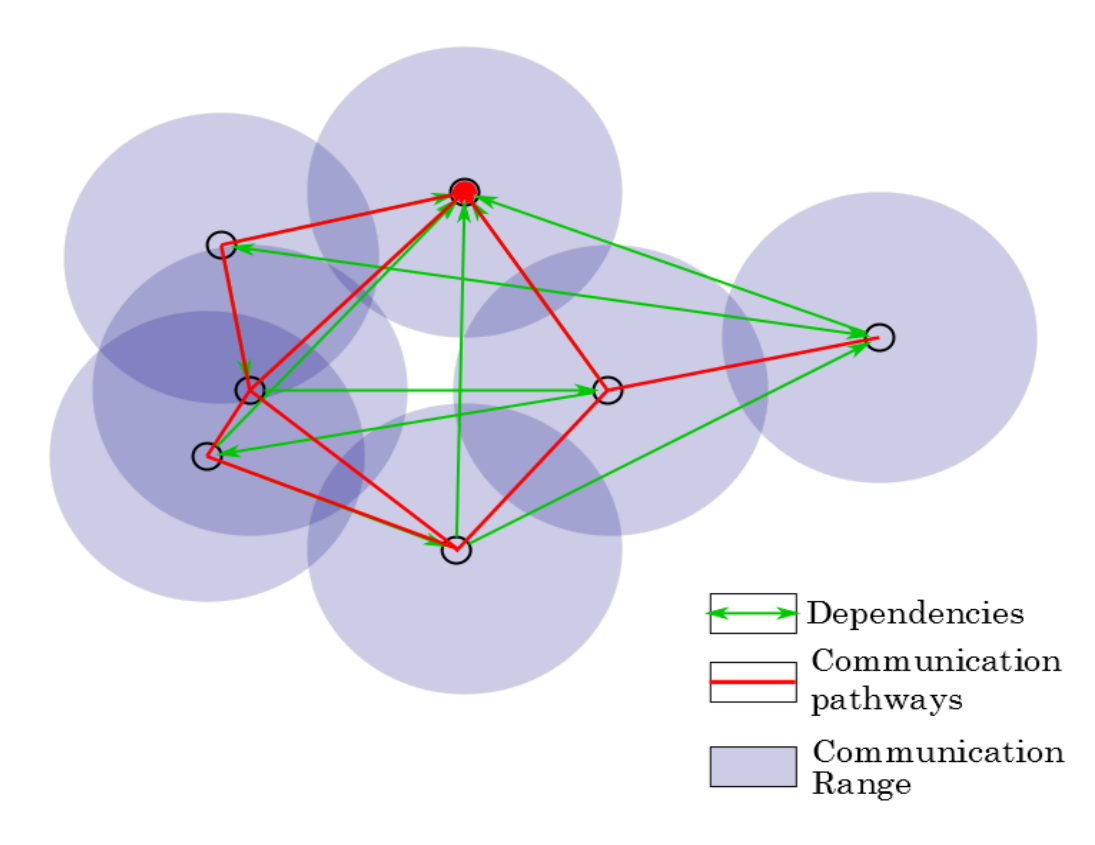


Testbed System - Structure

- Written in Java
- Designed using the principles of Dynamic Data-Driven Application Systems (DDDAS)
  - Allows simulation to run with real-world data in real time
  - Allows simulation to give feedback to real-world system
- Communicates with WebServices
- UI through Console



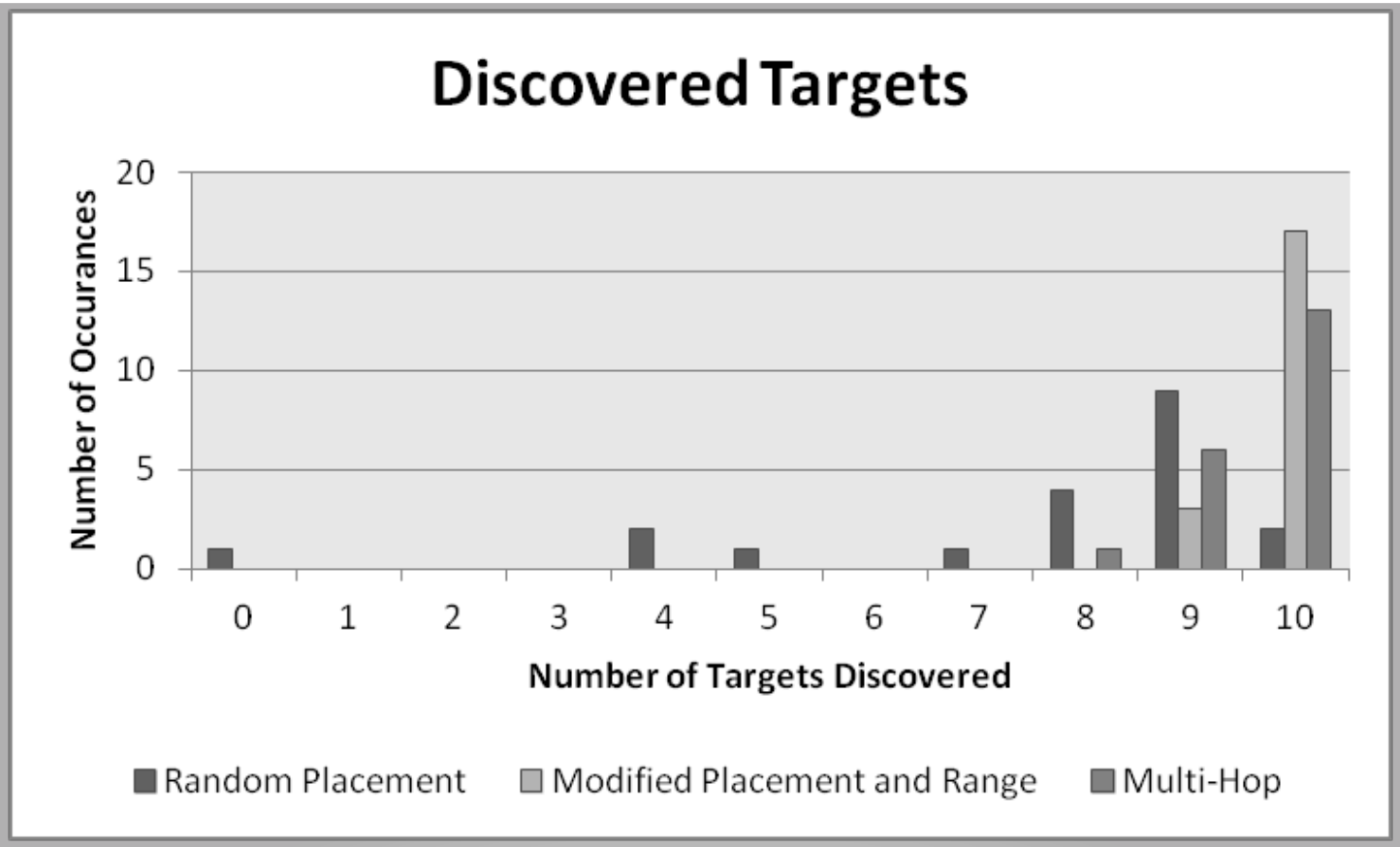
- Each agent given a circular range
- In order to communicate with first helper (leader), and second, communications must hop if out of range
- Can create an undirected graph
  - Helps compute optimal path



Implementation- Communication Range

Implementation- Single-Source Shortest Path

- Known algorithm for this problem: single-source shortest path
  - Given source node x and destination node y in a weighted undirected graph, find the shortest path from x to y
  - Weights: inverse powers of distances
    - Resembles communication fading
  - Source node: UAV who decides to communicate
  - Destination node: the helper it is trying to communicate with
- Not complicated – about $O(n^2)$ time
- What if UAV goes out of range?
  - Currently, communication with that UAV often lost, unless another comes within range again



- Note: Modified Placement runs fix the starting position of each UAV, as opposed to random. They also move the waypoints the leader follows toward the corners of the world.

Results- Targets Discovered

Results- Effect of Communication Range

Multi-Hop Communication	
Communication range (px)	Avg. Targets found (out of 10)
75	9.6
60	9.6
50	9.2
40*	8.6

- Note: Not all runs were completed because UAV communications broke down. Thus no experiments with smaller ranges were attempted

- Multi-Hop communications
  - More realistic
  - Perform at least as well as “idealized” wireless communications (range the size of the entire world)
  - Ratio of communications range to field size affects number of targets found and number of collisions
    - all experiments were performed using a 150px x 150px field
  - Time to complete mission is longer for a higher number of targets
  - For our world size, a range between 50 and 60 px most accurate, with least communication loss
- Fixed start position of UAVs helps eliminate randomness
  - More consistent reporting of number of targets found

Conclusions

Future Work

- Procedure in case of isolation from swarm
  - Track last known location of leader in case of isolation
  - Still not entirely resolved, swarm tends to drift towards top left corner when isolated from the leader. Not really an issue with high enough communication ranges
- Runs for different world sizes
  - Would be useful to know ratio between world size and UAV communication range
    - Then could calculate optimal range for a particular world easily
    - Less need to recover a UAV that has gone out of range, which can cost time

References

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Thank You!