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The Center for Education and Research in Information Assurance and Security

Resilient Multi-Robot Coverage Control Under Stealthy Cyberattacks

Kartik A. Pant, Vishnu Vijay, Minhyun Cho and Inseok Hwang

Problem Statement

- A group of robots deployed in an **environment** (in any arbitrary initial configuration) is moved to optimal locations that maximize the overall sensing/coverage performance.
- Certain robots are **attacked by adversaries (such as GNSS spoofing/ Denial of Service)** resulting in disruption of coverage task and the underlying network topology.

Our goal is to move the robots to **cover a desired area** while ensuring that they remain **well-connected** and **collaboratively** protect/guide each other under unknown localization drifts/failures caused by **faults or cyberattacks**.

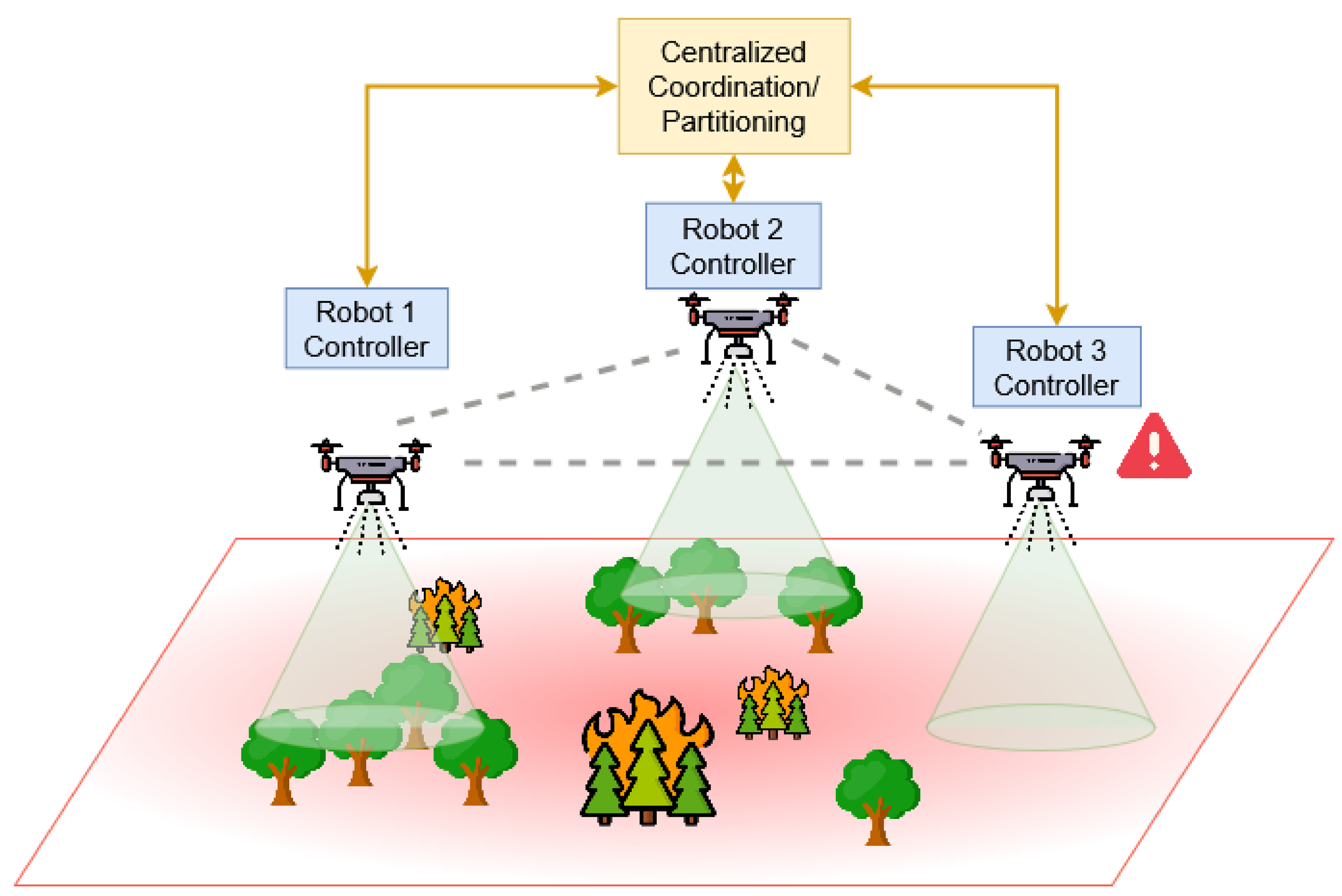
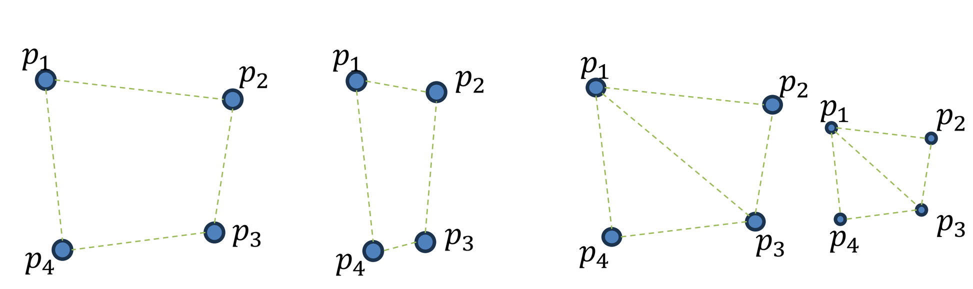


Illustration of multi-robot coverage control for **environmental monitoring** during wildfire. Our proposed **distributed** approach ensures the *coordination of the network of robots* even when some robots become **attacked** while executing the mission.

Bearing Maintenance For Coverage Control

- **Rigidity theory** investigates the **flexibility of graph networks**, classically studied for **bar-and-joint framework**.
- **Multi-agent system (MAS)** can be viewed as **joints** and their sensing network as an **invisible bars** connecting them[1].
- We transform the **coverage control problem** into **rigidity maintenance** of a **network** (or structure) formed by **robots** (as joints) and their virtual *sensing and communication links* (as bars) as it is scaled and translated in space.



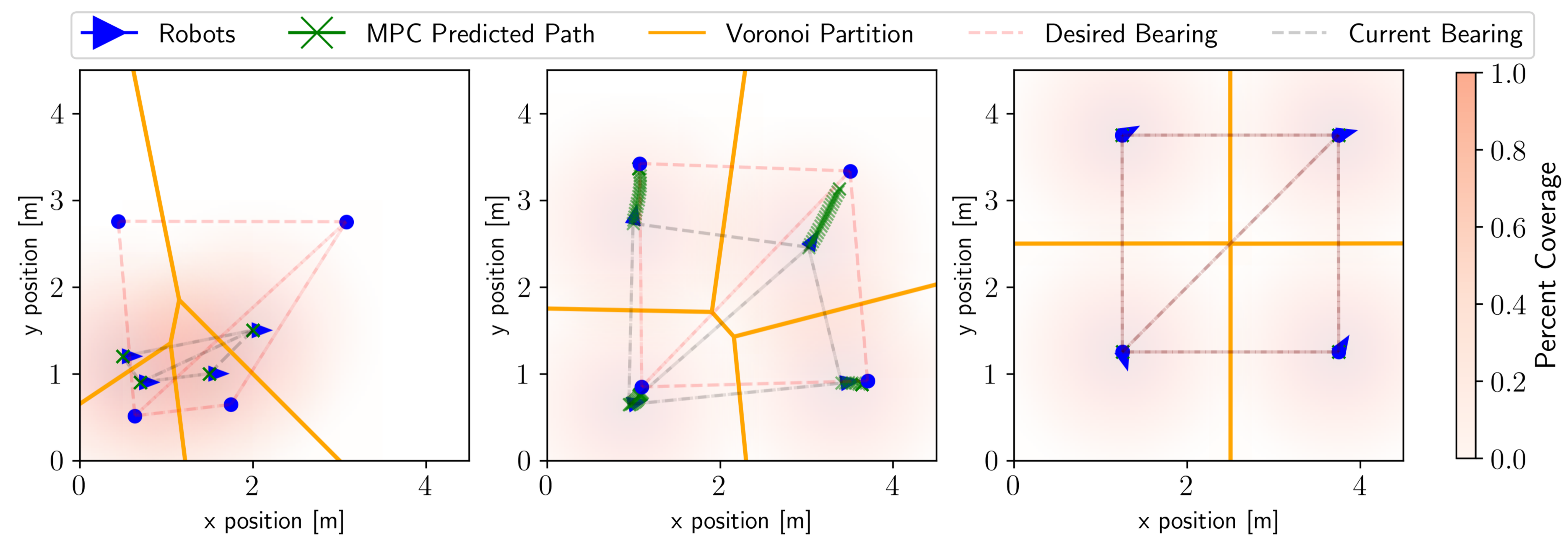
Bearing flexible graph — Bearing-rigid graph

Bearing-rigidty equips the MRS to have the following key properties essential for resilient MRS operations :

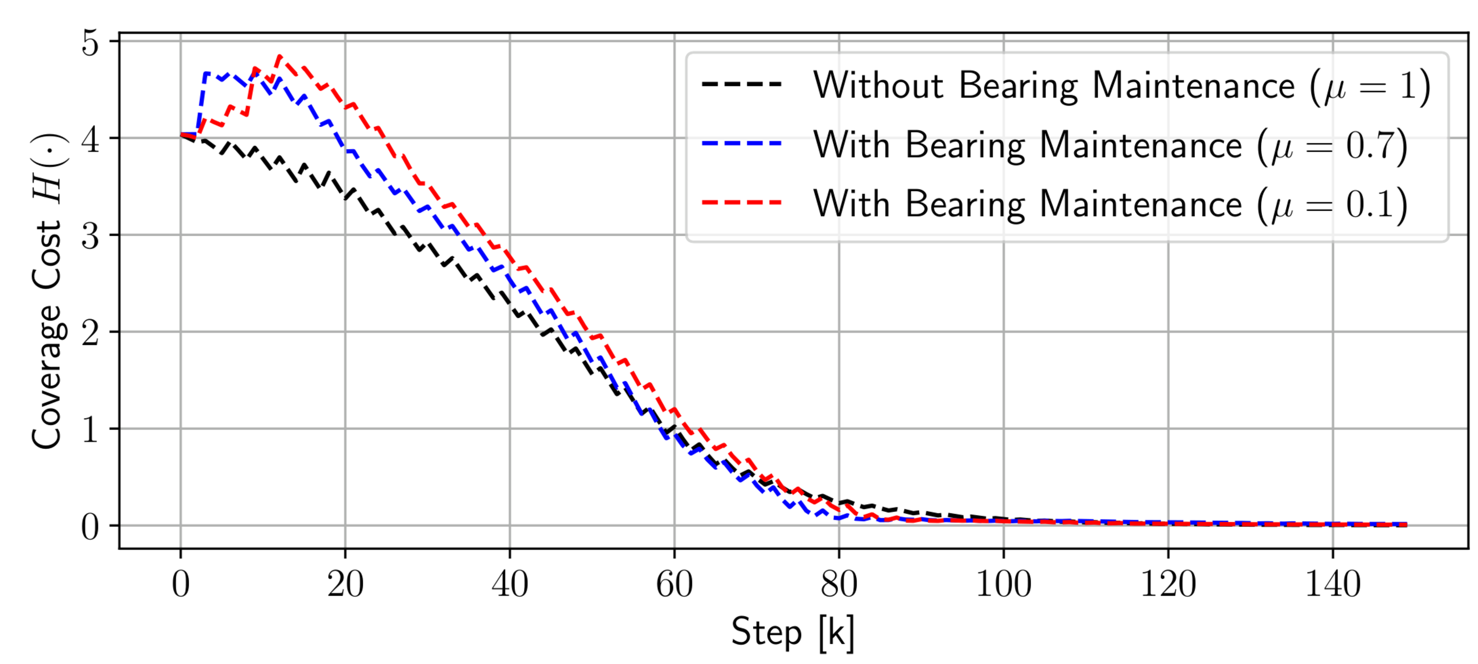
- Decentralized self-localization[1,2]
- Formation stabilization[2]
- Reconfiguration[3]

Key Idea: Given a feasible target configuration, the MRS should be steered towards it while maintaining a constant bearing formation (translation and scaling)

Simulation Results

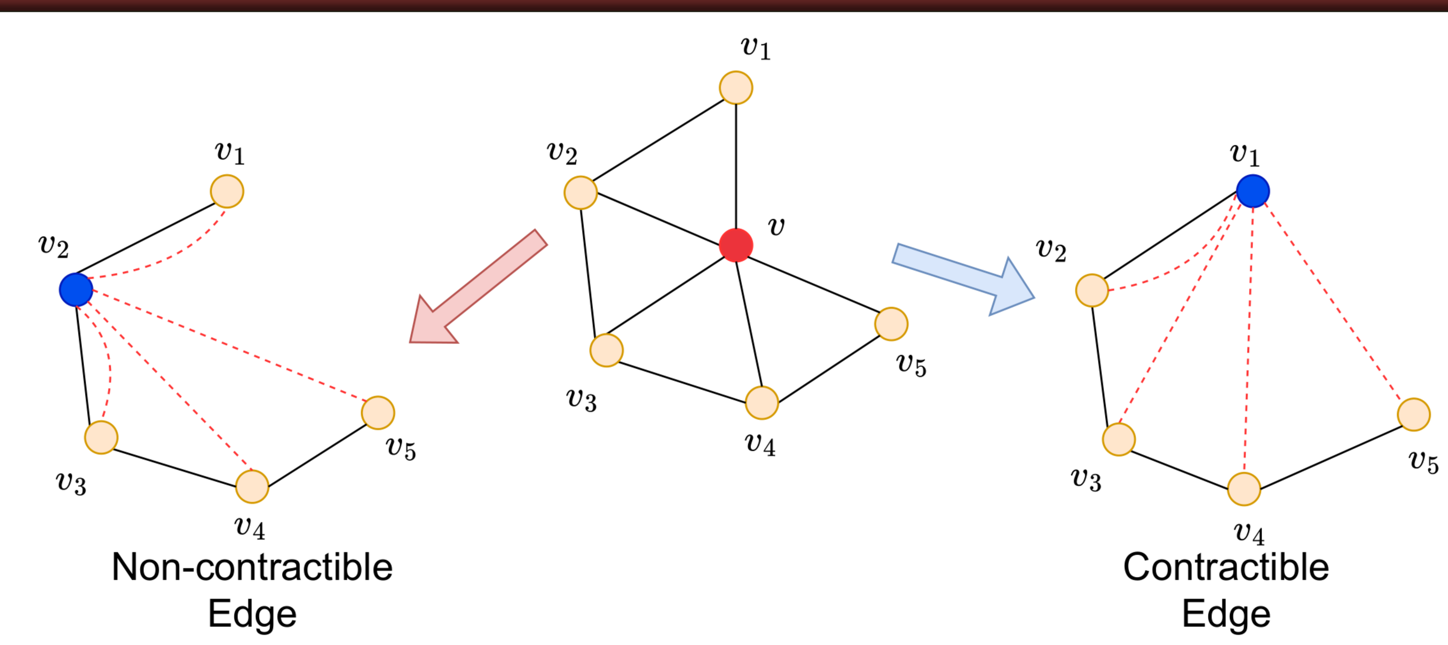


Robot positions and **Voronoi partitions** along with bearing formation at time $k = 0, 50, 140$

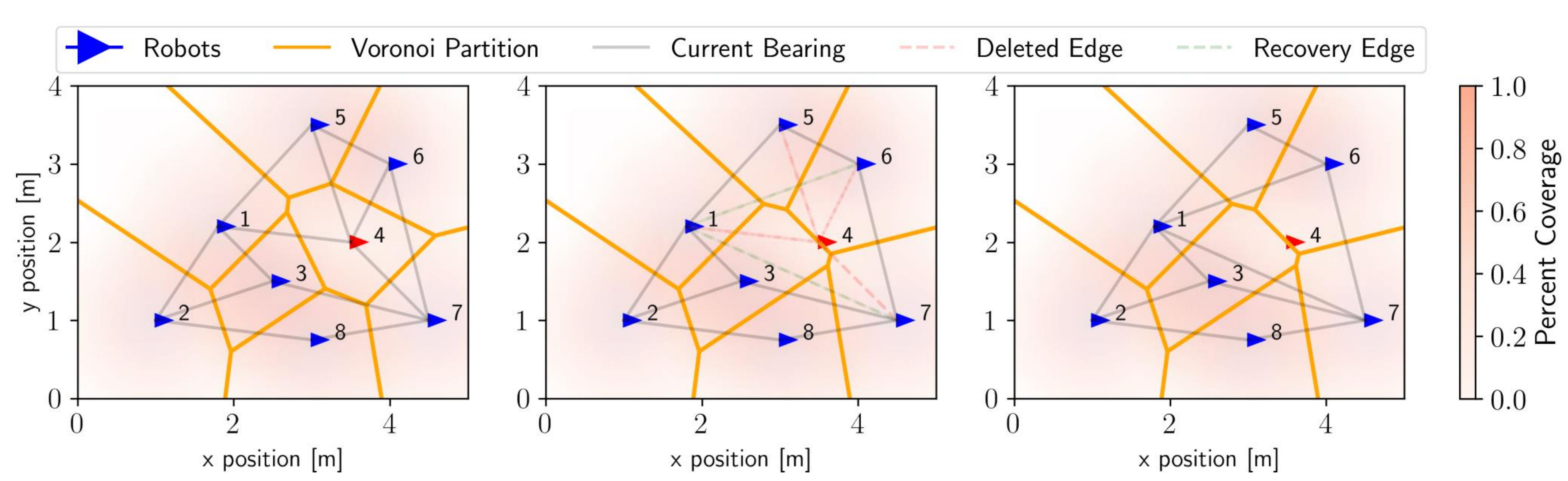


Coverage performance with increasing weights on **bearing maintenance**

Rigidity Recovery After Attack Detection



- We are only required to search **locally** for the **contractible edges** among the **2 −hop neighbors** of the robot.
- Check **all possible contractible edges** for the neighbor of each robot in the MRS network.



Rigidity recovery in the event of **loss** of robot 4. The neighbors of robot 4, i.e., robots 1,5, 6, and 7, utilize the **rigidity recovery algorithm** to identify $(1,6)$ and $(1,7)$ as the new set of edges for rigidity recovery.

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[1] S. Zhao and D. Zelazo, "Bearing rigidity and almost global bearing- only formation stabilization," IEEE Transactions on Automatic Control, vol. 61, no. 5, pp. 1255–1268, 2015
[2] S. Zhao and D. Zelazo, "Bearing-based distributed control and estimation of multi-agent systems," in 2015 European Control Conference (ECC), pp. 2202–2207, IEEE, 2015.
[3]B. D. Anderson, C. Yu, B. Fidan, and J. M. Hendrickx, "Rigid graph control architectures for autonomous formations," IEEE Control Systems Magazine, vol. 28, no. 6, pp. 48–63, 2008

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