Intercession d'enchères pour plus d'initiative mixte dans les algorithmes décentralisés d'allocation de tâches multi-robots basés sur le consensus

Présentation JFSMA’24

8/11/24

Victor Guillet, Christophe Grand, Charles Lesire, Gauthier Picard

Presentation Outline

1. Research objectives and motivating case

2. Problem definition

3. Proposed approach: Bid Intercession

4. Results Overview

Background (1–2)

Proposal (3–4)

Research objectives and motivating case

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AGENCE INNOVATION DÉFENSE

Research Objectives

- How to distribute a mission/tasks to the various agents in a (heterogeneous) multi-robot system, ensuring that they are carried out collectively

- Synchronising the execution of each robot's actions

- Taking account of operational constraints such as loss of communication

- Link with the operator in drawing up the plan and repair strategies

Example: Search & Rescue

https://rrl.robocup.org/

Agents

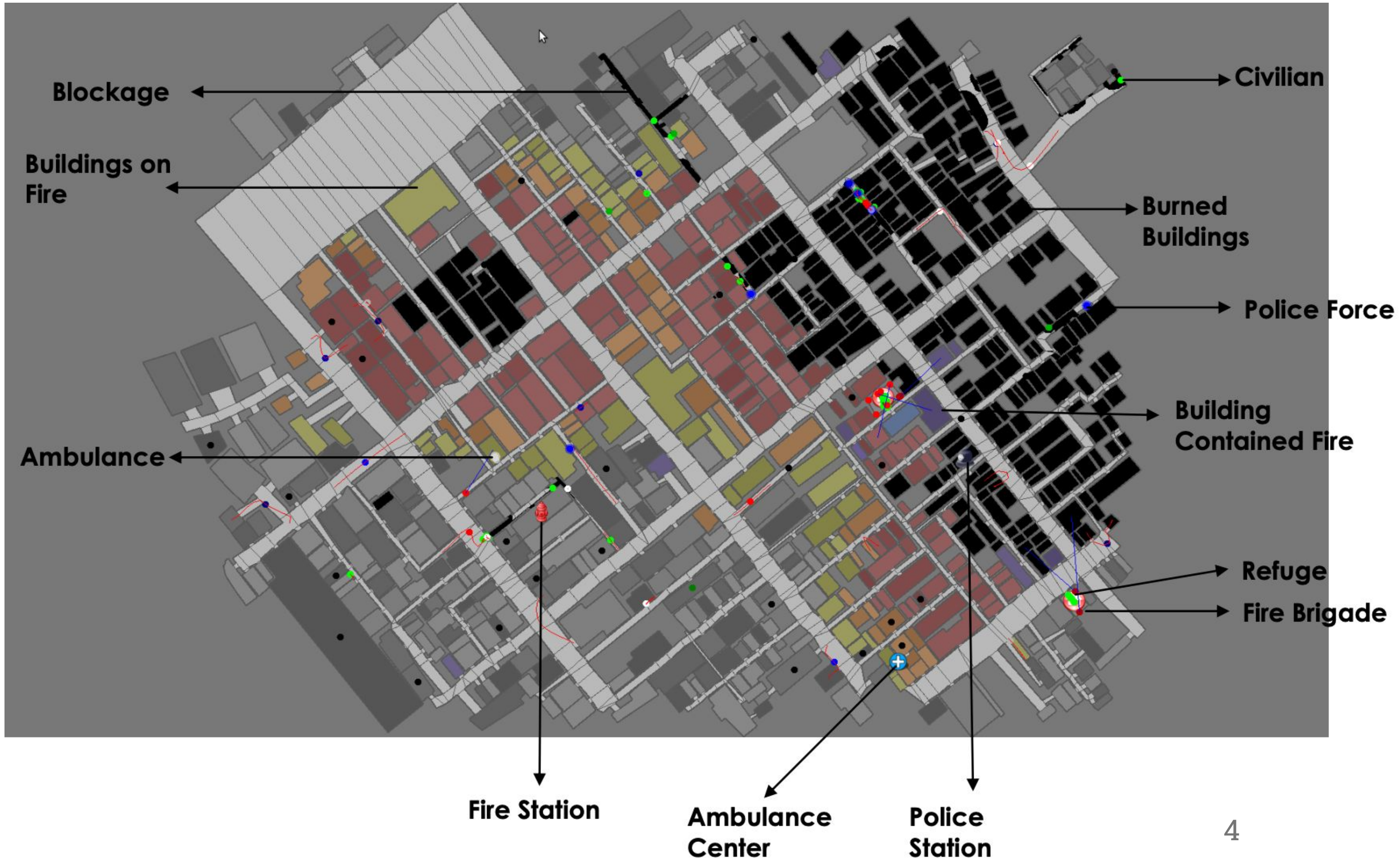
- Ambulance Team
- Fire Brigade
- Police Force

Tasks

- Rescue civilians
- Extinguish fires
- Clear blockades
- Refill supplies

Infrastructure locations

- Ambulance Centre
- Fire Station
- Police Office
- Refuge / Shelter



Why consider multi-robot systems?

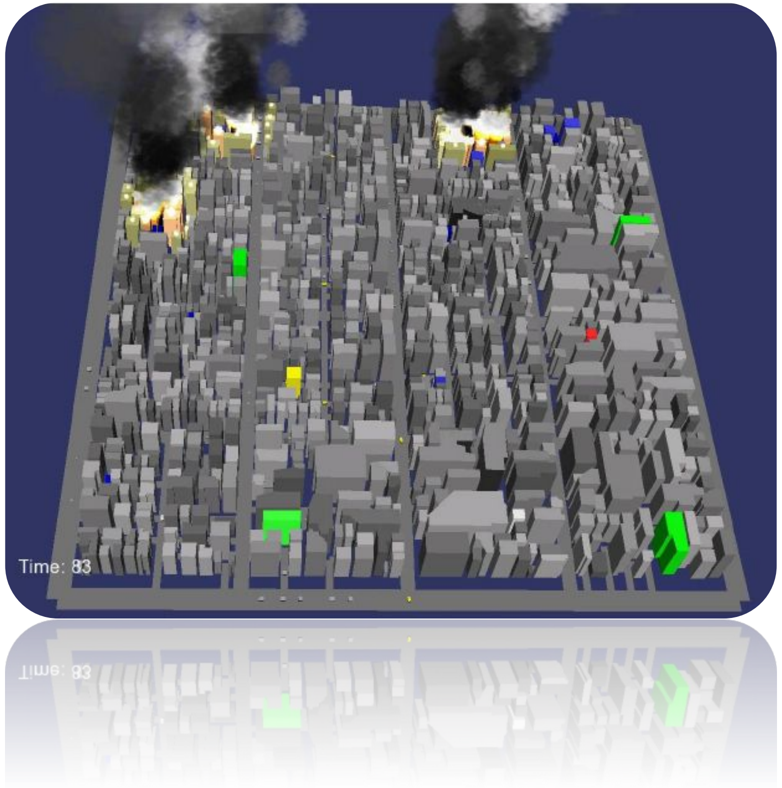
Limitations of human responders:

- Limited accessibility in hazardous areas.
- Time constraints and human endurance.
- Risks to human lives in unstable environments.

Advantages of robotic multi-agent systems :

- Increased efficiency in covering vast areas.
- 24/7 operational capability without fatigue.
- Minimised risk to human responders.

Key Challenges



https://rrl.robocup.org/

- Multi-Robot Task Allocation problem
- Large number of actors involved
- Heterogeneity in actors and tasks/task requirements
- Incomplete information
- Limited resources
- Dynamic scenario state
- Real-time decision making

Problem Definition

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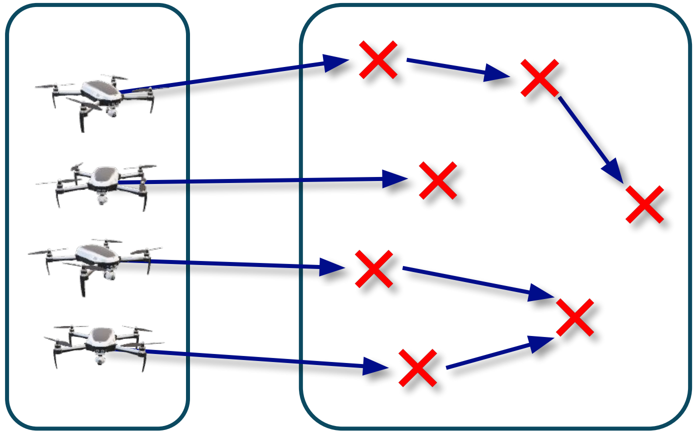
Multi-Robot Task Allocation (MRTA)

Finding the answer to the question:

"Who does what, when, and in what order?"



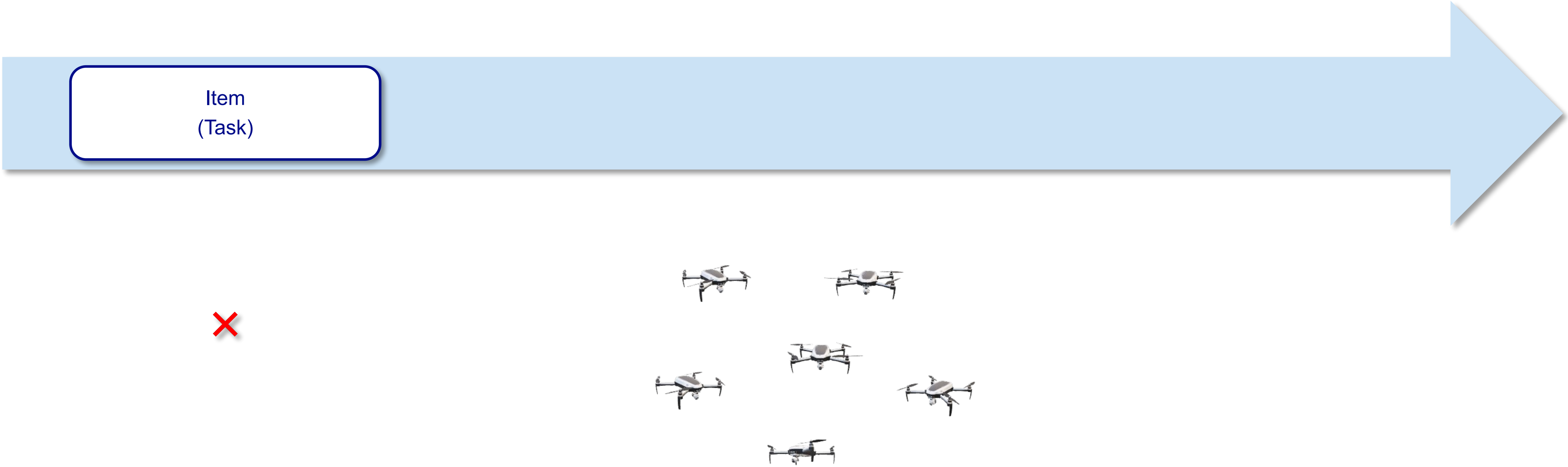
General optimization goals:

Meet task requirements while maximising performance and optimising resource utilization

- Meet tasks requirements
- Maximise the rate at which tasks are undertaken
- Minimise the overall cost of task completion to the group

Market-Based Approaches

> Inspired from real world auction mechanisms



Market-Based Approaches

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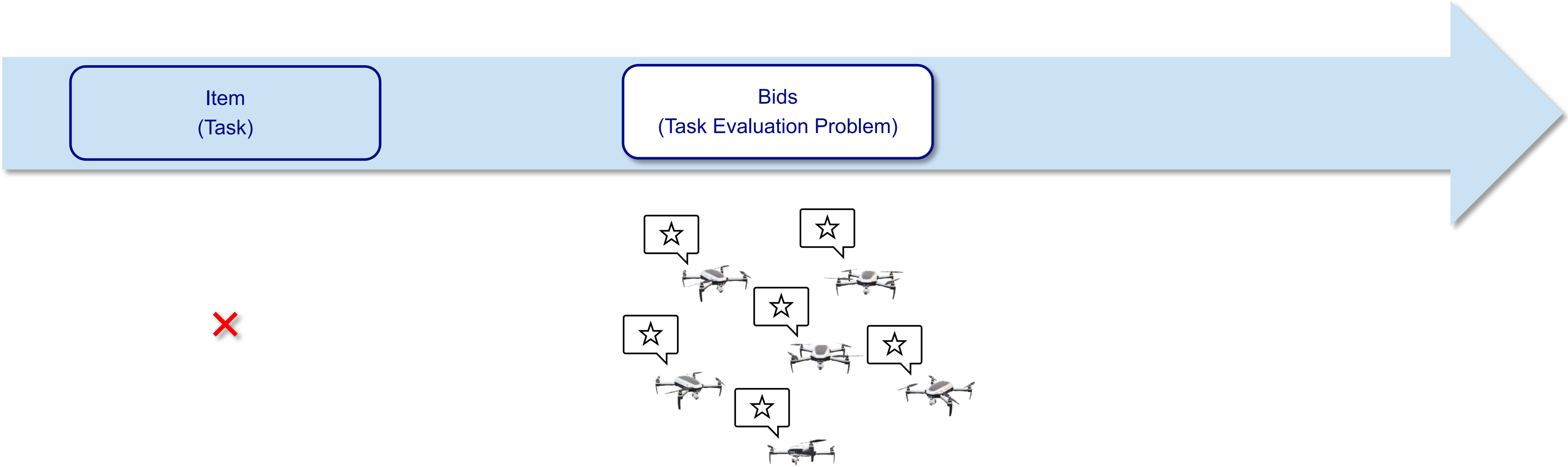

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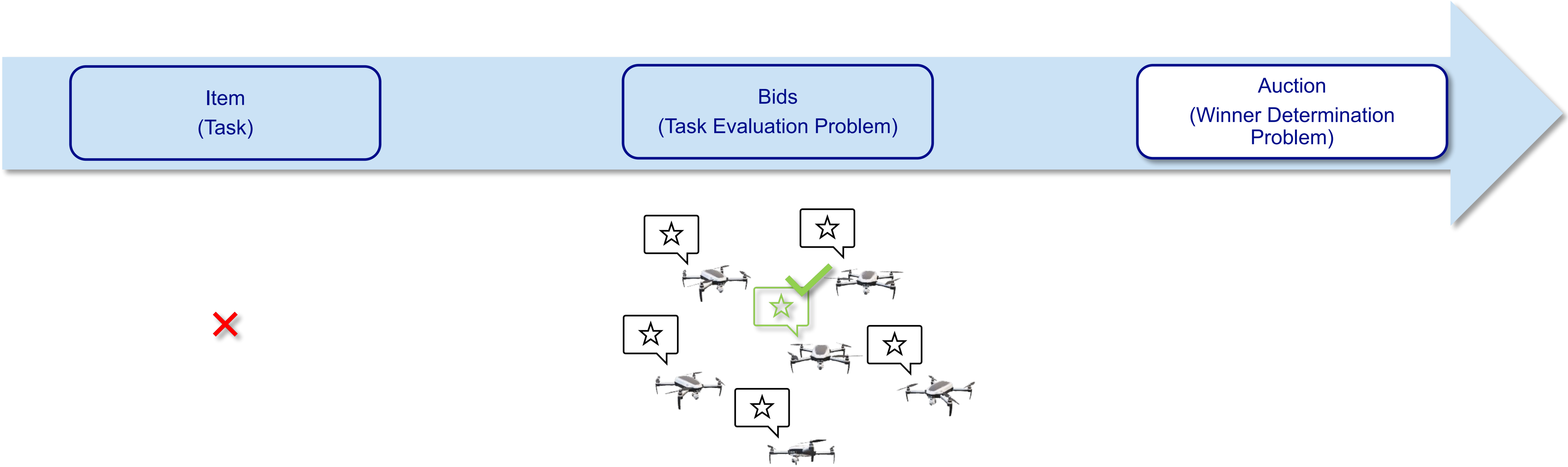
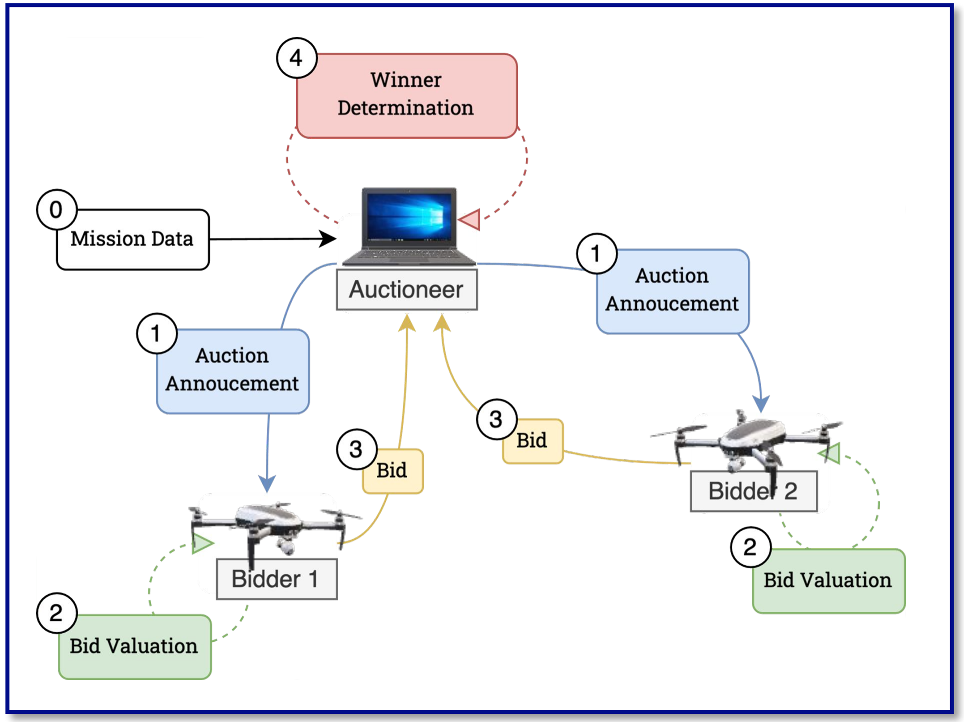
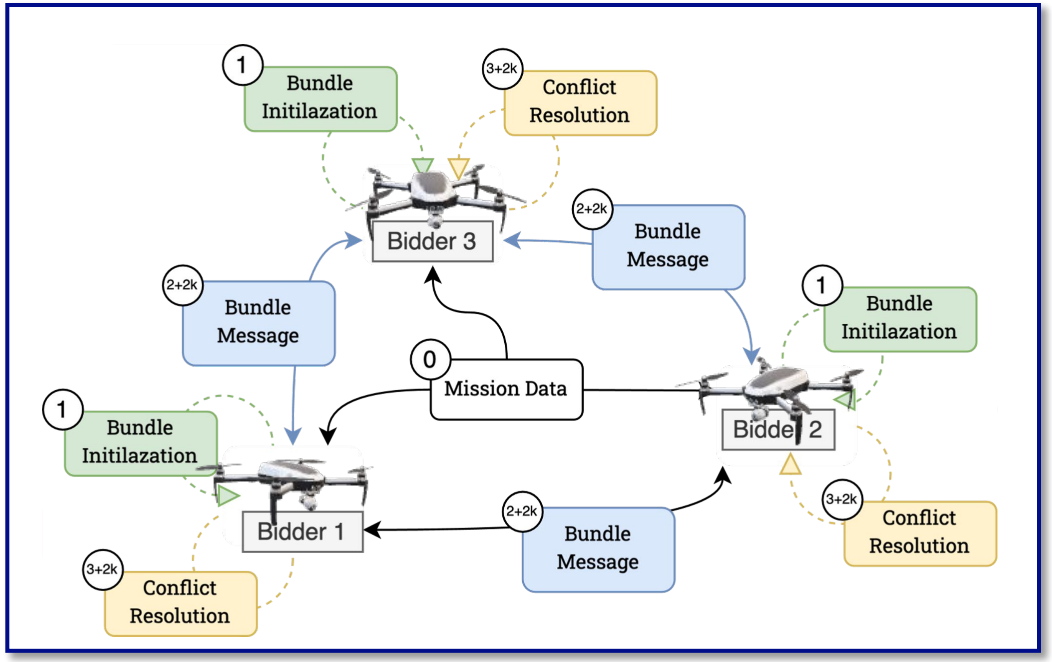


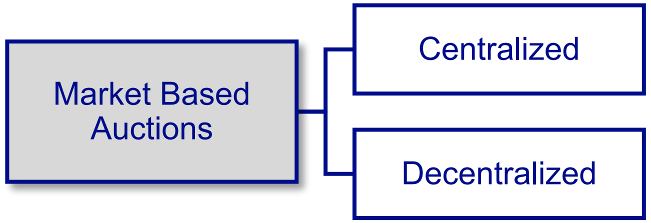
Centralized Auction-Based Methods vs Consensus-Based Methods



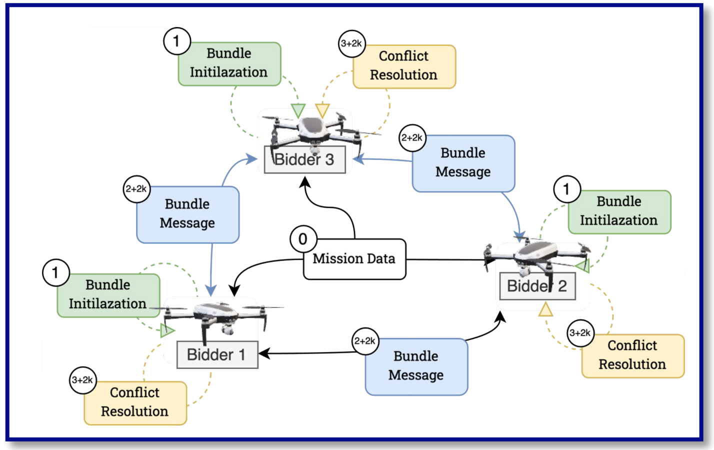
Centralized

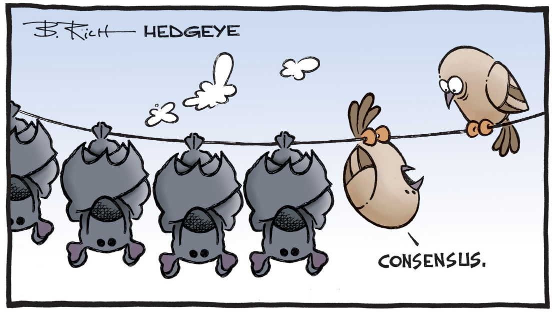


Decentralized



F. Quinton, C. Grand, and C. Lesire, Market Approaches to the Multi-Robot Task Allocation Problem: A Systematic Mapping and Survey





Consensus-Based Algorithms

H.-L. Choi, L. Brunet, and J. P. How, Consensus-Based Decentralized Auctions for Robust Task Allocation, IEEE Transactions on Robotics, vol. 25, no. 4

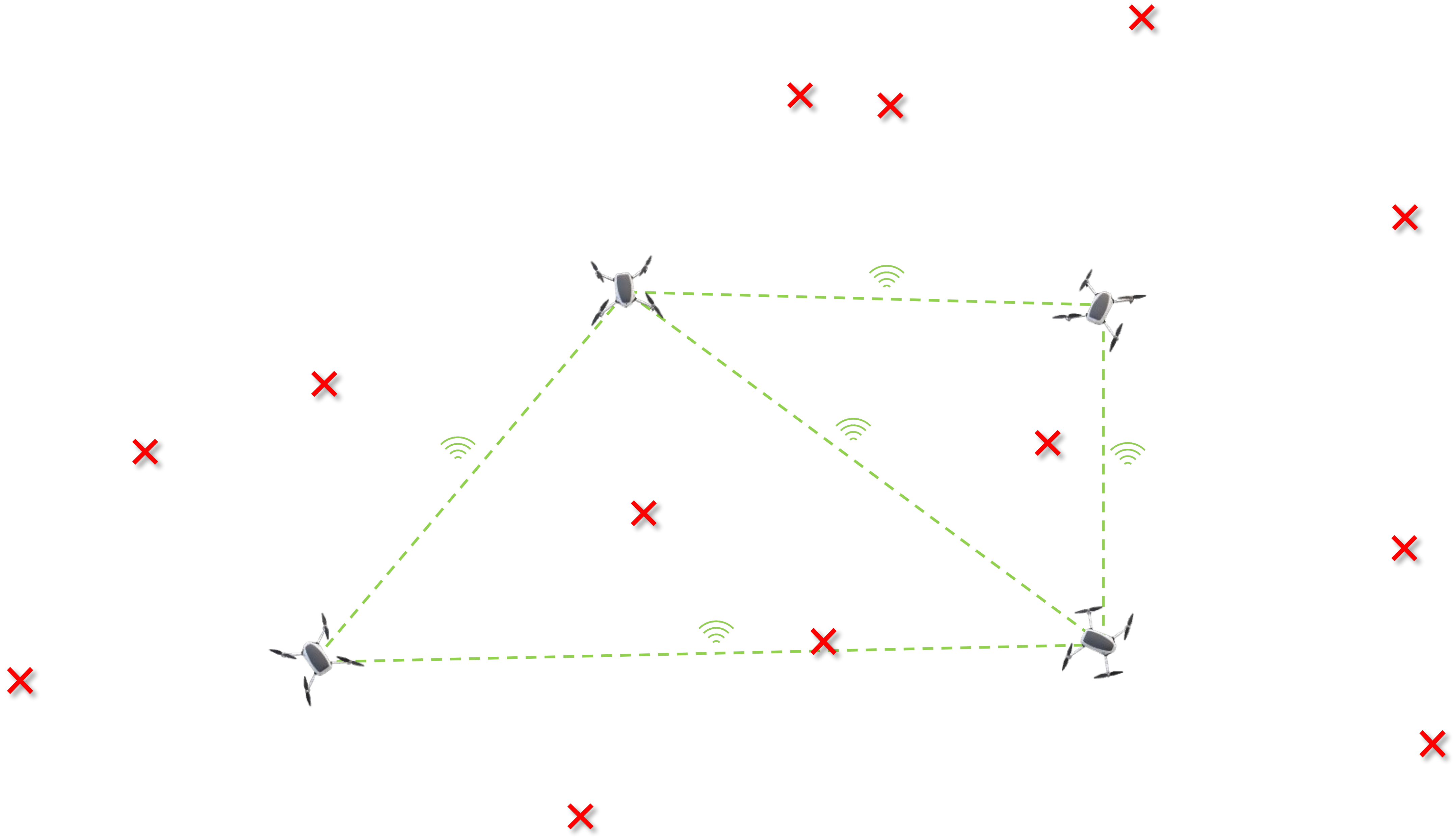
Consensus-Based Auction Algorithm

CBAA

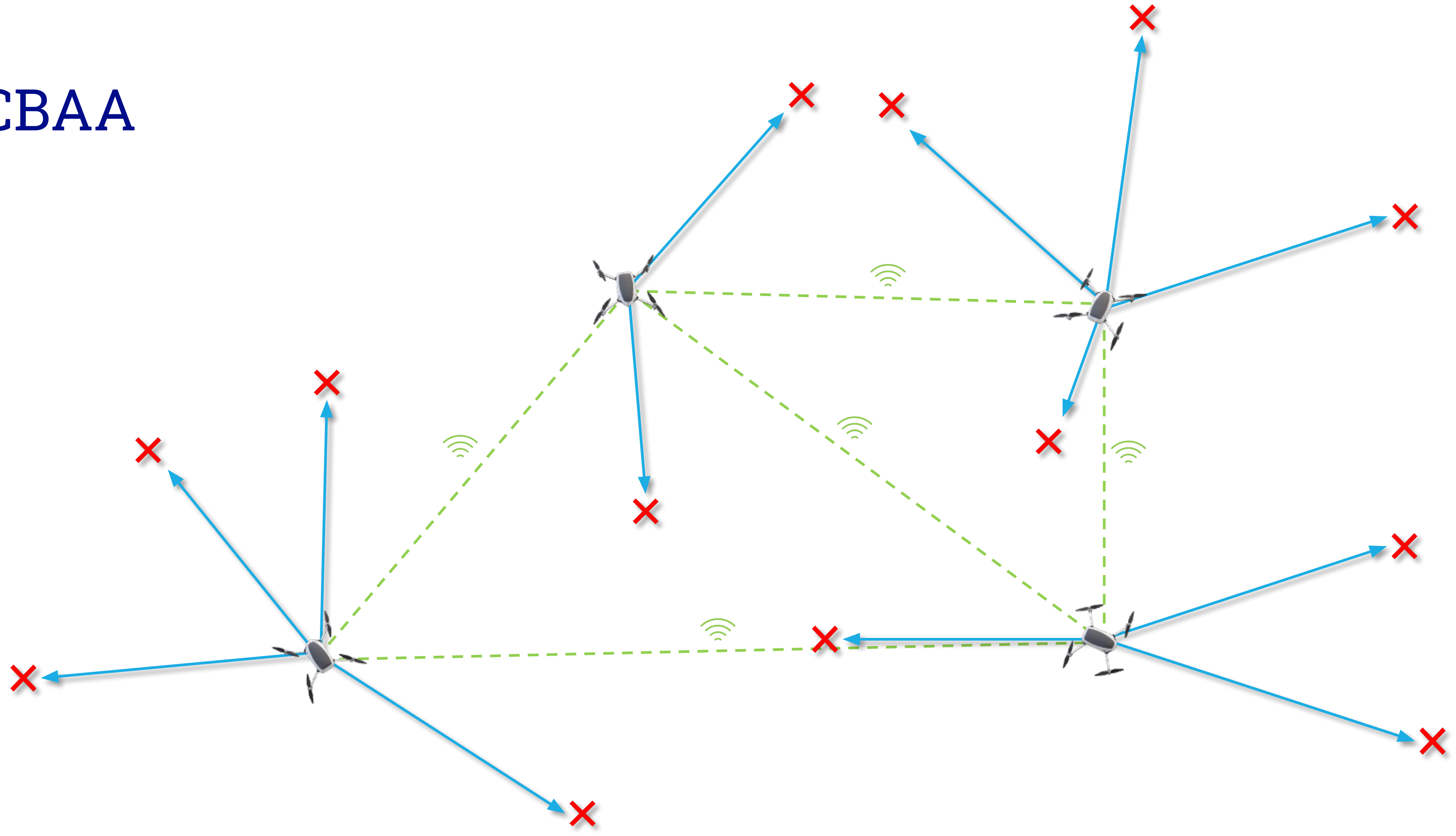
Consensus-Based Bundle Algorithm

CBBA

- Market Based Auctions
  - Centralized
    - ...
  - Decentralized
    - CBAA
    - CBBA



CBAA



Bid Intercession

1. Motivating case

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"intercession"

Noun

The action of <u>intervening</u> on behalf of another.

"bid intercession"

-

The action of <u>bidding</u> on behalf of another

- Bid intercession involves imposing bids on target agents in an auction process through prioritization mechanisms.
- This allows for influencing auction outcomes without altering the fundamental allocation protocol.

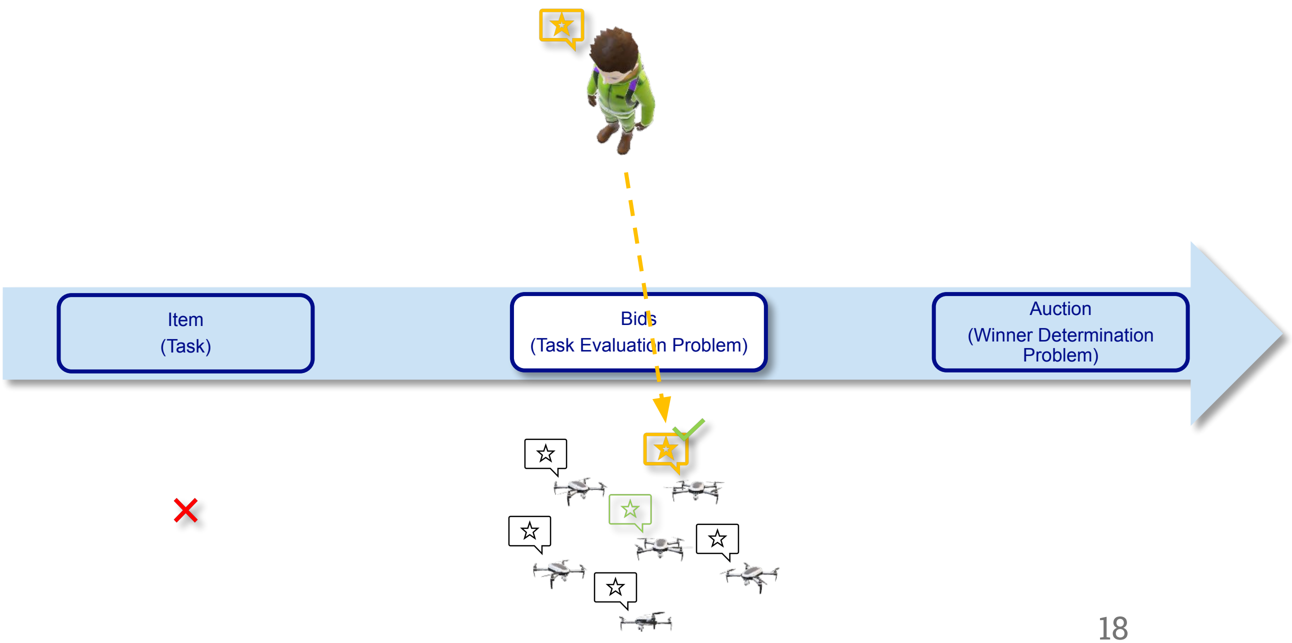
Additional rules introduced in the Task Evaluation Problem

Bid intercession

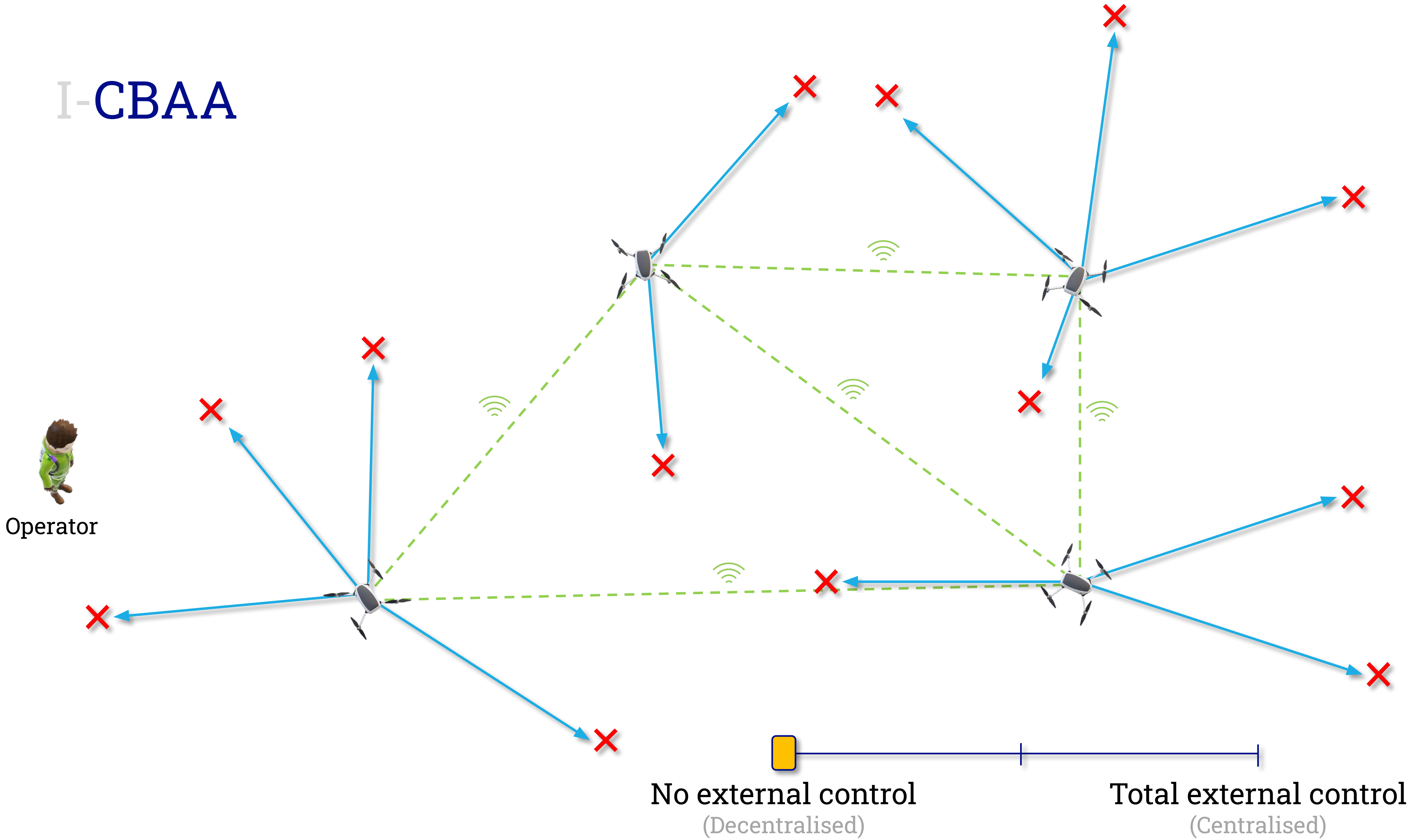
- Override tasks evaluations during the auction process
  - Leverage different scoring scheme to evaluate tasks
  - Introduces an additional mechanism based on priority levels to determine which task evaluation to adopt during the auction process
- Does not impact convergence properties of the underlying algorithms
- Allows for various degrees of control over the allocation process

"[...] whatever knowledge each agent scoring scheme is based on [...], **the conflict resolution process of (CBBA) is insensitive to the details of each agent's scoring scheme.**"

H.-L. Choi, L. Brunet, and J. P. How, Consensus-Based Decentralized Auctions for Robust Task Allocation

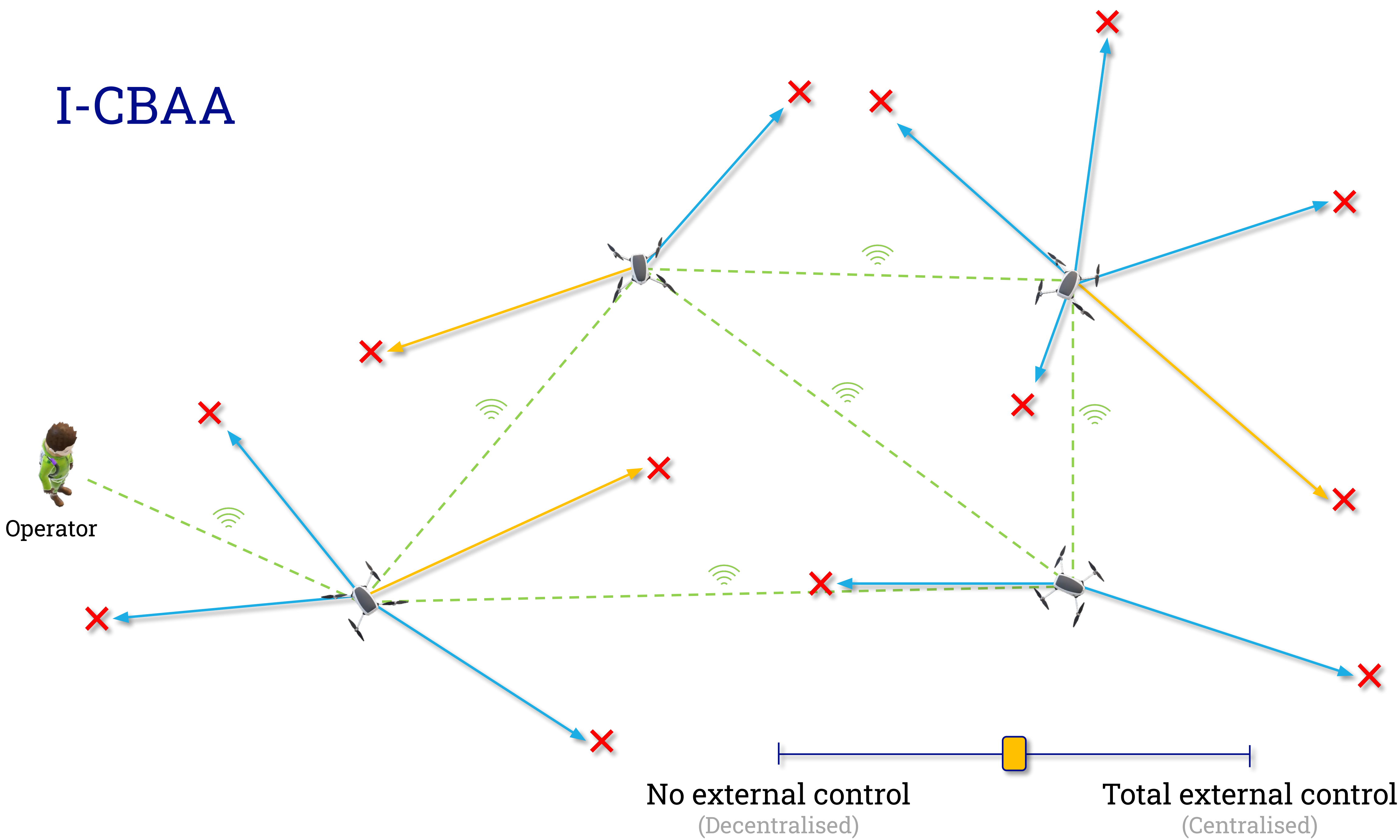


I-CBAA



Operator
No external control
(Decentralised)
Total external control
(Centralised)

I-CBAA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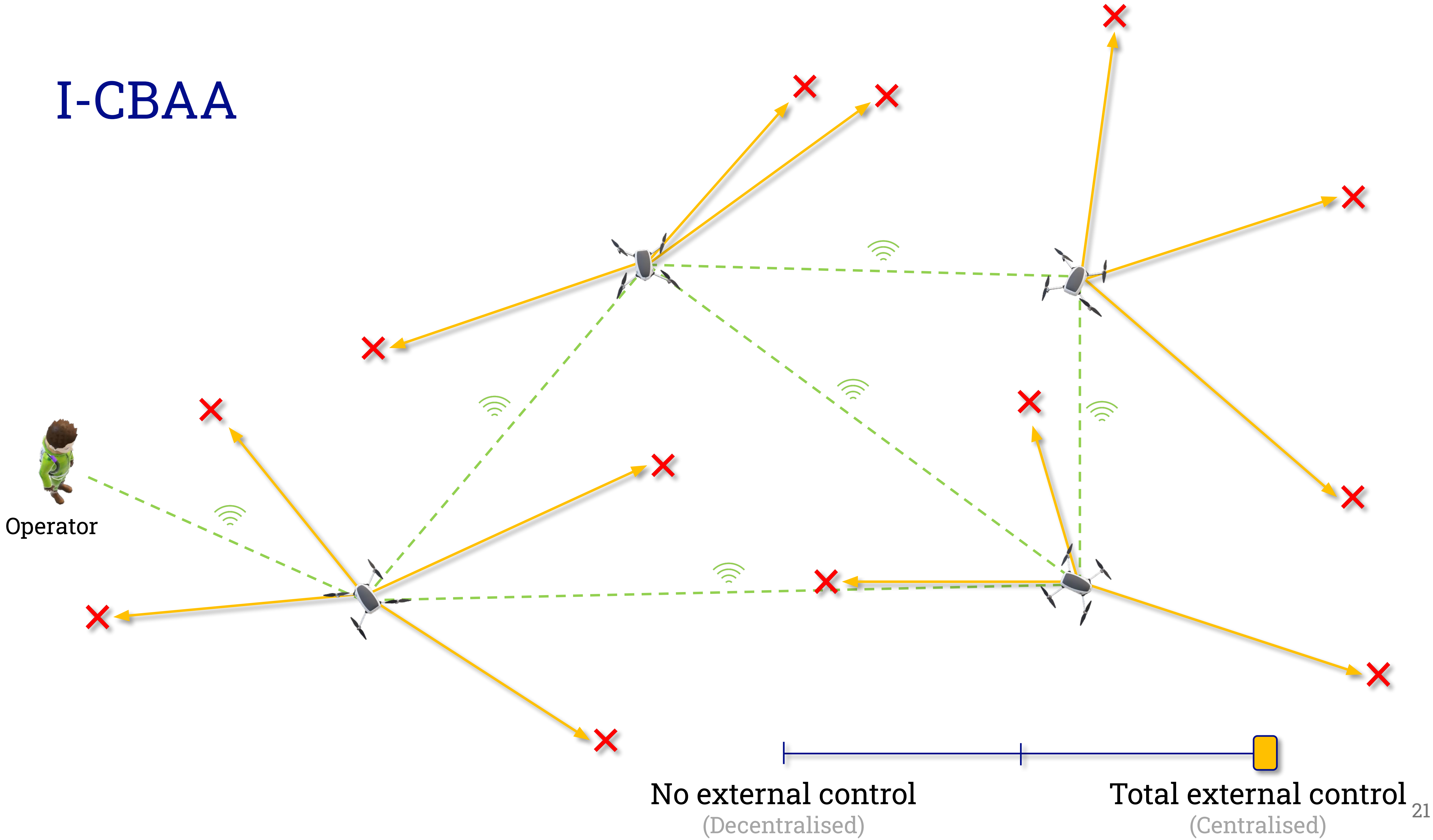
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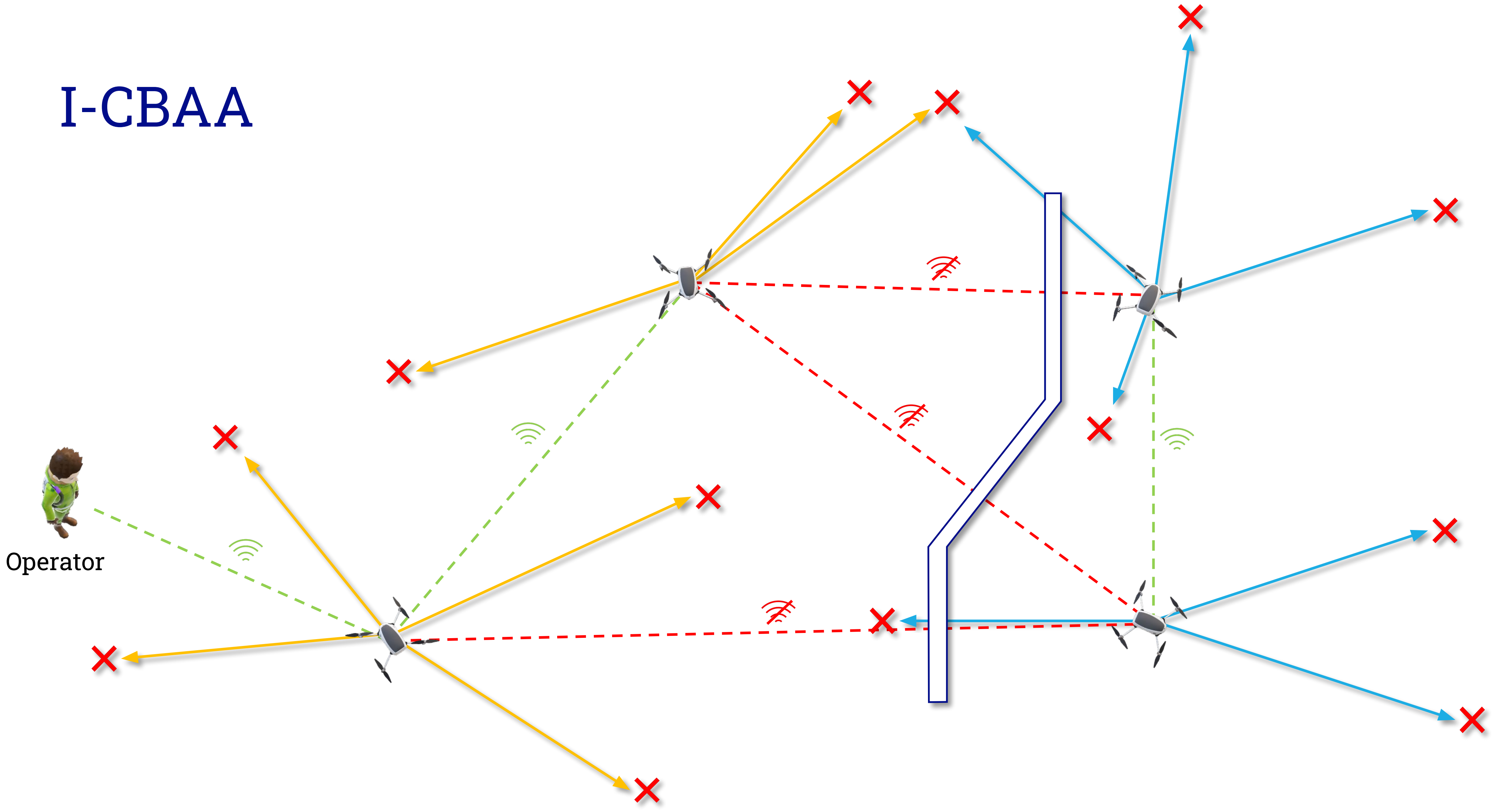

Robust to communication failure

Results Overview

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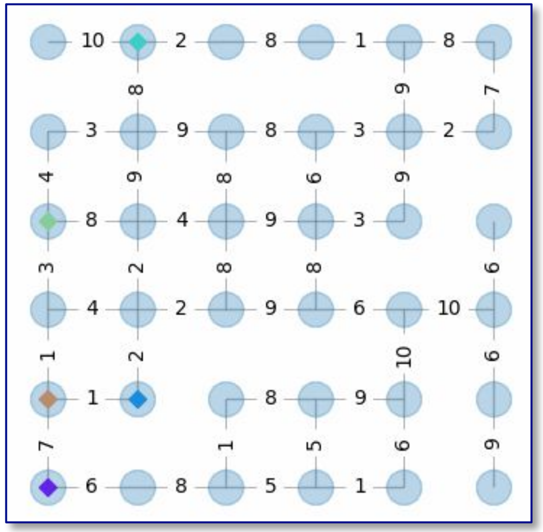
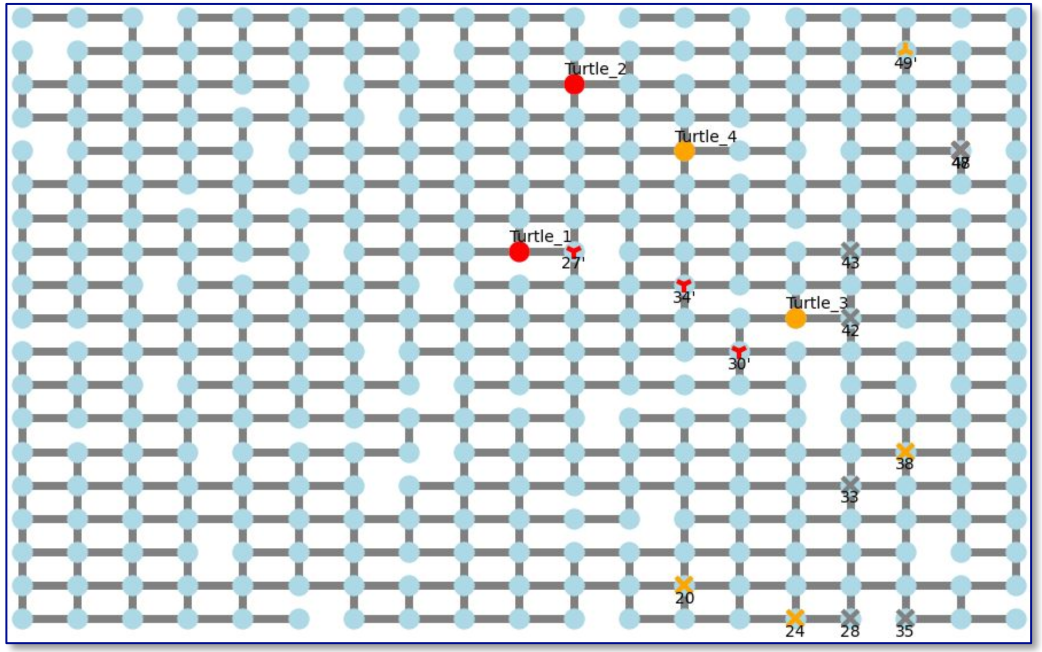
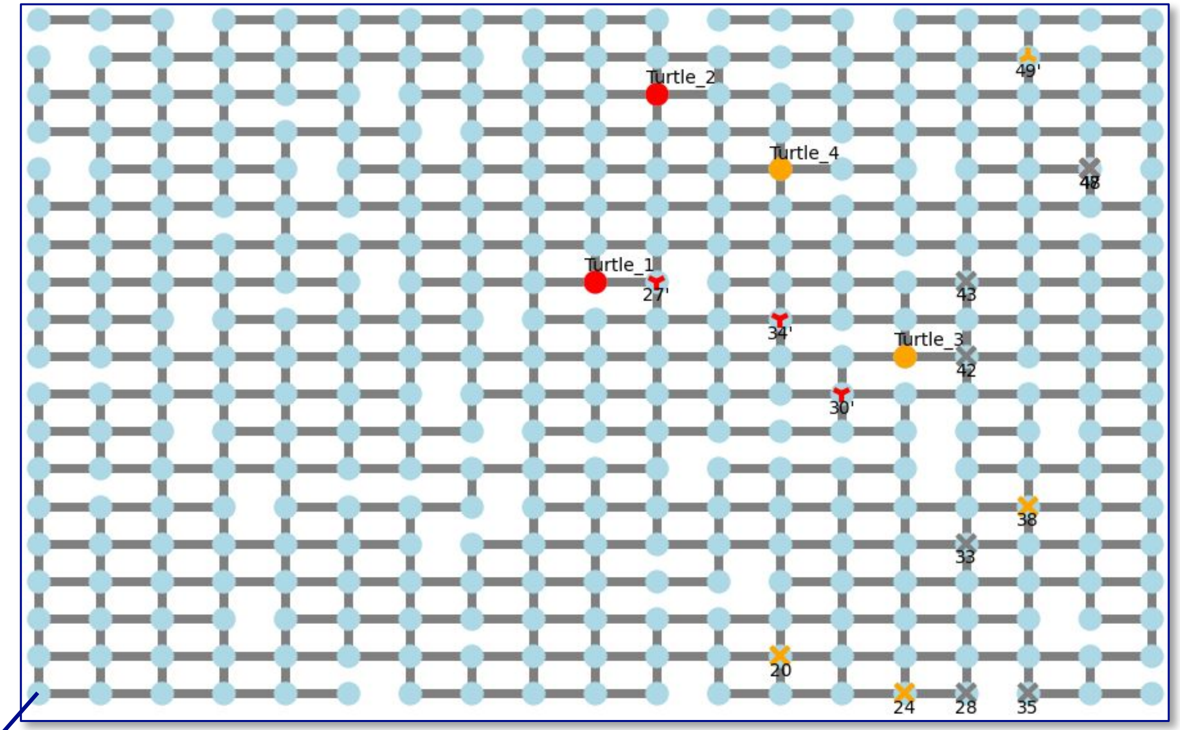
Technical work

- **MAAF**: **M**ulti-**A**gent **A**llocation **F**ramework
  - ROS2 based
  - Development and Test framework for multi-agent allocation protocols
  - Support both simulations and real operations
  - Includes analysis and visualisation tools for run logs





Experimental setup



Start

Experimental setup:
- 4 agents (2 types: types A or B)
- 50 GOTO followed by: ACTION tasks (types A or B) or nothing
- Task released gradually from closest to furthest from start

Robots:
- Only aware of GOTO tasks locations and observed ACTION tasks (location and nature)

Operator:
- Same as above + aware of what ACTION tasks are found at which GOTO locations

Goal: Use intercession to **inject operator knowledge into the solution** to ensure robots take on GOTO tasks followed by ACTION tasks they can complete

Evaluation metrics:
- % matched allocation
- Step count
- GOTO tardiness (from release)
- ACTION tardiness (from release)
- Message count

Results

Table 1. Average values (and standard deviation) over 10 instances of performance metrics for each configuration and algorithm

$\overline{a_1}, \overline{a_2}$	$\overline{s_1}, \overline{s_2}$	Algorithm	Total step count	Total tardiness	Total goto tardiness	Total action tardiness	% matched alloc.	Total msg count
25, 25	2, 2	CBAA	756.8 (±7.6%)	3263.7 (±16.3%)	2460.5 (±26.1%)	803.2 (±54.1%)	50.4 (±11.3%)	1449.9 (±2.0%)
25, 25	2, 2	I-CBAA	538.0 (±11.1%)	1795.0 (±19.4%)	1785.7 (±19.4%)	**9.3 (±141.4%)**	**98.2 (±2.6%)**	**1243.1 (±1.6%)**
25, 25	2, 2	CBAA$^+$	487.6 (±6.6%)	1823.3 (±12.0%)	1410.2 (±11.3%)	413.1 (±40.9%)	52.6 (±12.3%)	2393.5 (±2.8%)
25, 25	2, 2	I-CBAA$^+$	**423.2 (±5.8%)**	**1416.8 (±10.3%)**	**1353.0 (±9.8%)**	63.8 (±53.5%)	89.2 (±2.8%)	2100.7 (±1.8%)
20, 20	2, 2	CBAA	611.2 (±9.5%)	2584.3 (±16.8%)	2103.1 (±20.7%)	481.2 (±28.4%)	51.8 (±11.4%)	1319.9 (±2.0%)
20, 20	2, 2	I-CBAA	519.6 (±7.7%)	1814.5 (±11.7%)	1806.2 (±11.6%)	**8.3 (±173.7%)**	**98.2 (±2.4%)**	**1136.2 (±1.5%)**
20, 20	2, 2	CBAA$^+$	452.0 (±11.9%)	1730.7 (±23.1%)	**1221.1 (±11.9%)**	509.6 (±55.5%)	45.2 (±17.8%)	2165.6 (±2.0%)
20, 20	2, 2	I-CBAA$^+$	**406.8 (±6.7%)**	**1415.9 (±10.9%)**	1332.6 (±10.0%)	83.3 (±54.8%)	88.5 (±4.7%)	1890.8 (±3.0%)
35, 5	2, 2	CBAA	710.4 (±11.6%)	2929.0 (±14.3%)	2085.6 (±13.5%)	843.4 (±42.7%)	38.5 (±25.3%)	1345.1 (±1.6%)
35, 5	2, 2	I-CBAA	660.0 (±12.1%)	2321.0 (±18.4%)	2022.7 (±18.1%)	298.3 (±42.0%)	66.2 (±13.2%)	**1173.5 (±1.2%)**
35, 5	2, 2	CBAA$^+$	467.2 (±10.1%)	1656.1 (±21.3%)	**1200.9 (±20.3%)**	455.2 (±56.0%)	39.8 (±18.9%)	2141.6 (±4.3%)
35, 5	2, 2	I-CBAA$^+$	**459.2 (±6.5%)**	**1500.8 (±17.1%)**	1279.9 (±15.2%)	**220.9 (±43.3%)**	**69.8 (±14.1%)**	1884.3 (±1.8%)
39, 1	1, 3	CBAA	1427.2 (±12.5%)	5810.2 (±10.8%)	1939.7 (±17.6%)	3870.5 (±19.4%)	7.5 (±66.7%)	1299.1 (±1.3%)
39, 1	1, 3	I-CBAA	1526.0 (±11.6%)	5805.8 (±17.2%)	2506.5 (±18.8%)	3299.3 (±33.5%)	23.8 (±24.9%)	**1255.0 (±0.6%)**
39, 1	1, 3	CBAA$^+$	834.3 (±12.9%)	3080.1 (±12.4%)	**1045.4 (±14.1%)**	2034.7 (±19.8%)	7.0 (±32.8%)	1987.4 (±1.6%)
39, 1	1, 3	I-CBAA$^+$	**809.2 (±12.4%)**	**3055.8 (±12.2%)**	1610.5 (±17.4%)	**1445.3 (±33.3%)**	**25.8 (±22.0%)**	1981.9 (±2.3%)

Conclusions

- Novel **intercession** mechanism to forster human intervention within consensus-based task allocation mechanisms
- Small overhead and **minimal modification** of the base algorithms
- Maintain the **convergence** properties

- Validation using **ROS-based simulation**

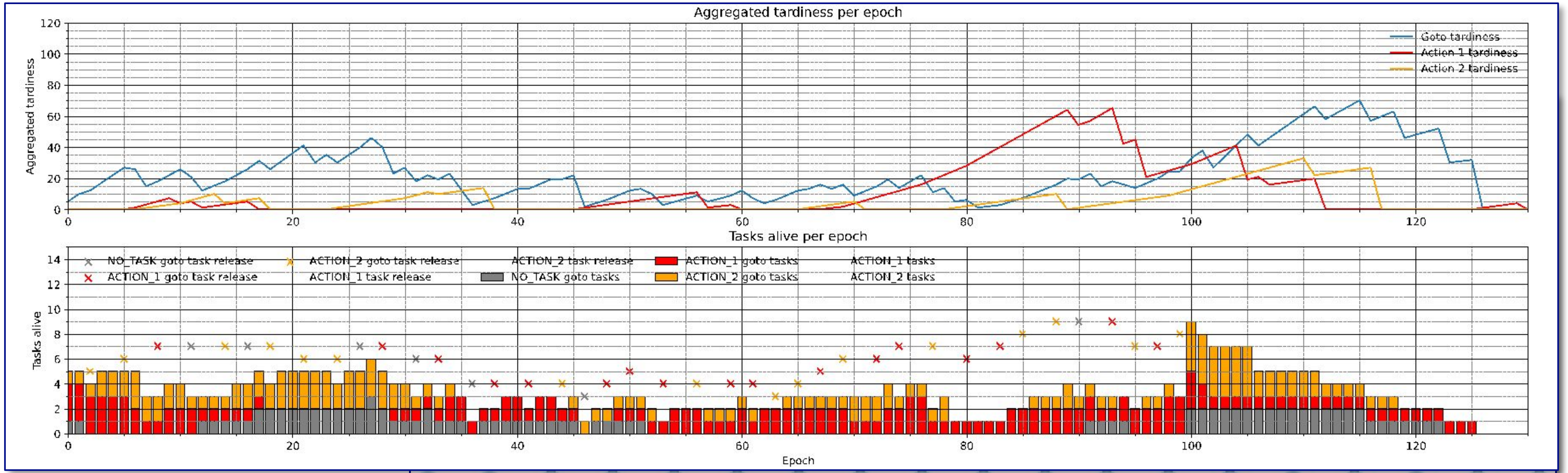
Future works

- Extension of other consensus-based algorithms (e.g. CBBA)
- Group formation and group intercession
- Study the impact of several levels of interventionism
- ROS implementation: towards deployment on real robots
- Envisioned scenarios CoHoMa challenge

Questions?

Results

CBBA



I-CBBA
(full intercession)