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The Center for Education and Research in Information Assurance and Security

ADAPTIVE TASK ALLOCATION TO HETEROGENEOUS AGENTS

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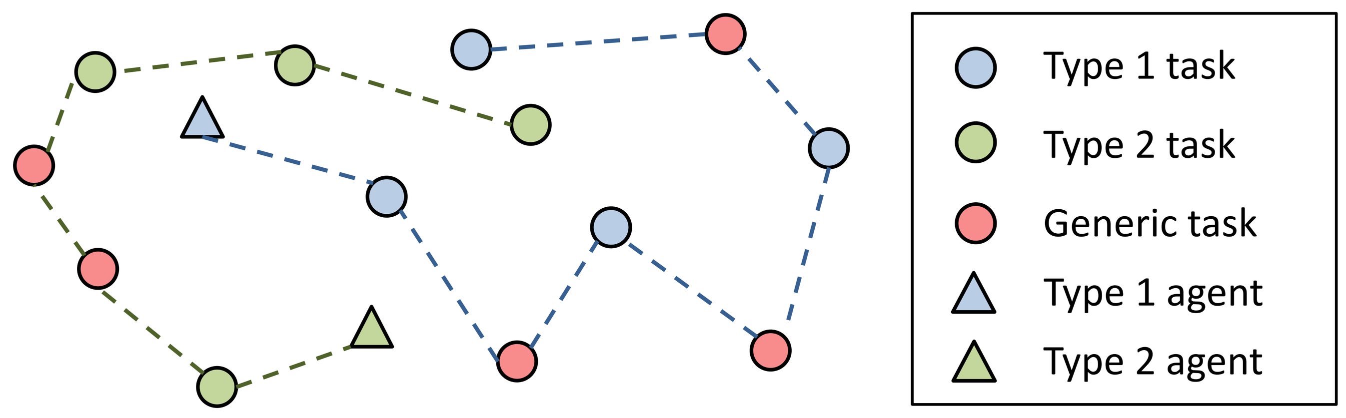
General Framework

Given:

- A set of k heterogeneous agents $\mathcal{A} = \{A_1, A_2, \ldots, A_k\}$, where each agent belongs to one of m types.
- Set $D = \{v_1, v_2, \ldots, v_k\}$,where v_i denotes the start location of the i^{th} agent.
- A set of tasks T comprising of a set of generic tasks T_0 and sets of type-specific tasks T_i of each type i, $1 \le i \le m$.
- A complete graph G on the set of nodes $T \cup D$.



Objective: Find an allocation of tasks to agents such that

- all tasks are covered by at least one agent.
- task-agent compatibility constraints are met.
- maximum cost for any agent to complete its allocated tasks is minimized.

Problem Formulation

Heterogeneous Agent Path Problem (HAPP):

$$\min_{S_1, S_2, \cdots, S_k} \max_{1 \le j \le k} P_j^*(S_j)$$

$$\text{subject to } \cup_{j=1}^{k} S_j = T, S_i \cap S_j = \emptyset, \forall j \ne i,$$

$$S_j = V_j \cup R_j, \forall j \in \{1,2,\cdots,k\},$$

$$V_j \subseteq T_{f(j)}, R_j \subseteq T_0.$$

$P_j^*(\cdot)$: Cost of optimal path (starting from node v_j) on a given set of tasks

$f(j)$: Returns type of agent A_j

S_j: Tasks allocated to agent A_j

V_j: Type-specific tasks allocated to agent A_j

R_j: Generic tasks allocated to agent A_j

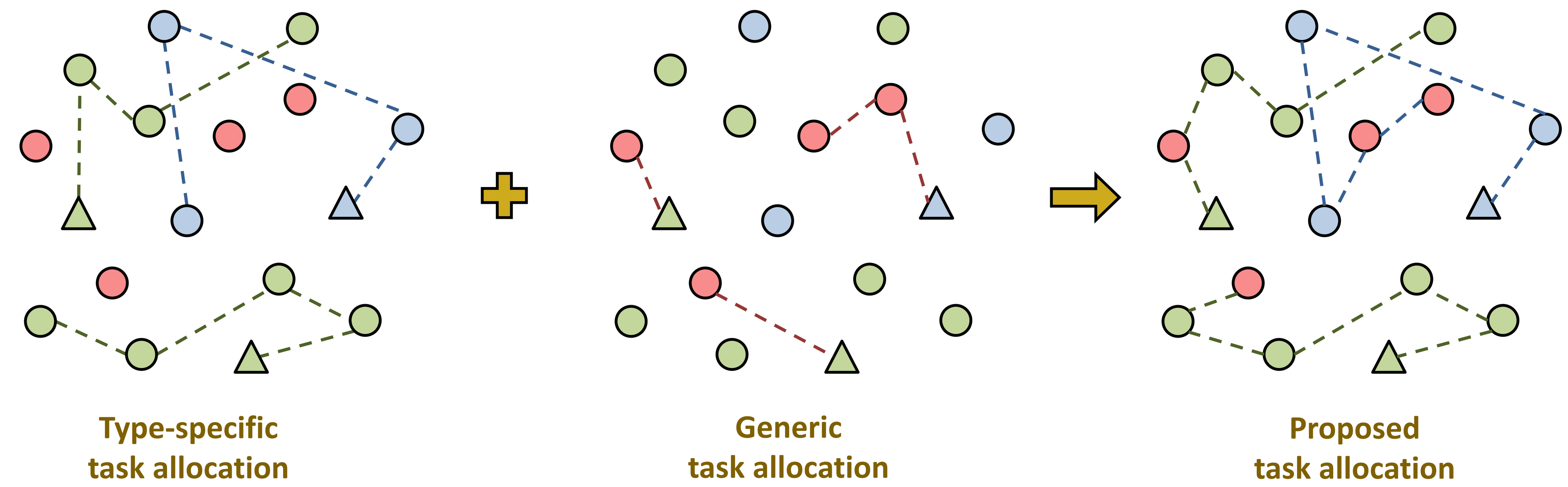
Salient Features

- Robust adaptive allocation of tasks to agents that **can handle failure of agents and cater to new tasks**.
- Most existing work on heterogeneous agents focuses on minimizing the sum of costs incurred by all agents. We minimize the maximum cost - **important in time critical applications** where maximum latency needs to be low.
- We consider **functional heterogeneity**. Most works encapsulate heterogeneity in terms of vehicle dynamics.
- Several works on paths for homogeneous agents to minimize min-max cost. We extend these works to task allocation to **heterogeneous** agents while **minimizing the maximum cost** of the path.

Key Idea:

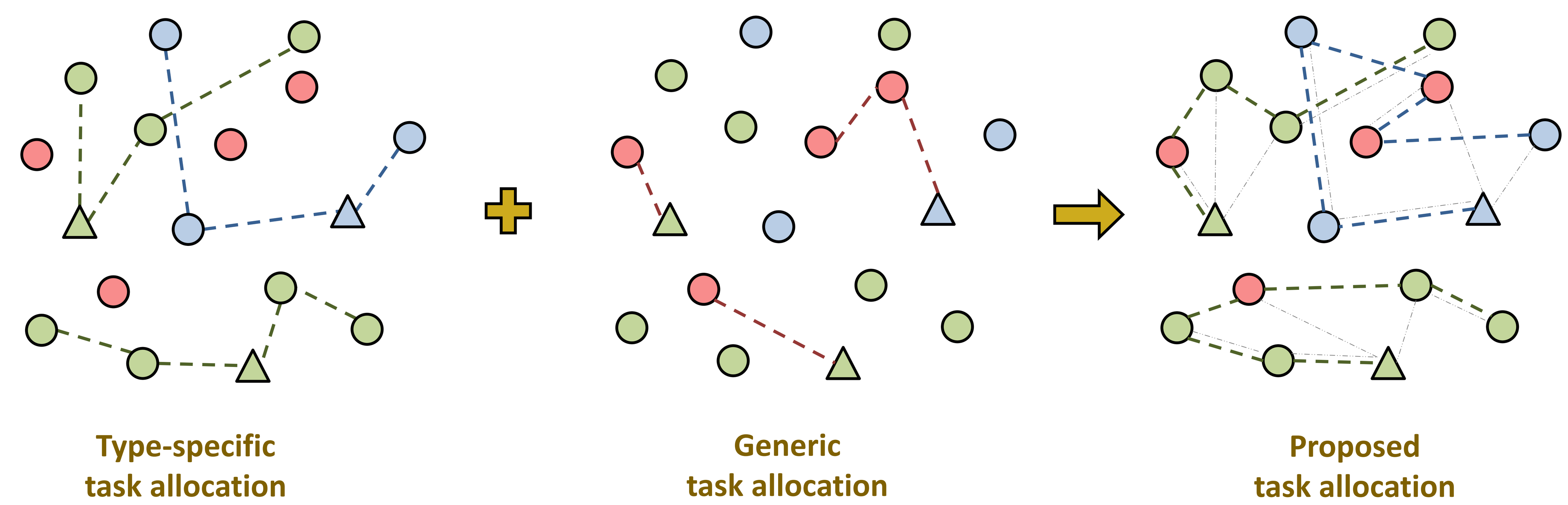
- Consider type-specific tasks and generic tasks separately. We can now use algorithms for homogeneous agent task.
- Two approaches: Path Split and Tree Split
- Existing algorithms for homogenous agent tasks allocation.
  - Min-max Path Cover Problem (Yu et. al., 2017).
  - Min-max Tree Cover Problem (Even et. al., 2004).

Approach 1: HeteroMinMaxPathSplit



- Solve homogeneous agent min-max path cover problem for each set of type-specific tasks T_i (for m_i agents, where m_i is the number of agents of type i).
- Solve the homogeneous agent min-max path cover problem on the set of generic tasks (for k agents).
- Combine the above two solutions to obtain a solution for HAPP.
- If an α-approximation algorithm is used to solve the homogeneous agent problem, we show that our algorithm to solve HAPP has an approximation factor of 3α.
  - Yu et. al. provide a 7-approximation solution to the homogeneous agent min-max path cover problem, which can be used to obtain a 21-approximation algorithm for HAPP.

Approach 2: HeteroMinMaxTreeToPath



- Solve homogeneous agent min-max tree cover problem for each set of type-specific tasks T_i (for m_i agents, where m_i is the number of agents of type i).
- Solve the homogeneous agent min-max tree cover problem on the set of generic tasks (for k agents).
- Combine the above two solutions to obtain a solution for HAPP.
- If a β-approximation algorithm is used to solve the homogeneous agent tree cover problem, we show that our algorithm to solve HAPP has an approximation factor of 4β.
  - A factor of two comes from combining the type-specific subtree and generic task subtree for each agent An additional factor of two is a result of converting trees to paths.
  - Even et. al. provide a 4-approximation solution to the homogeneous agent min-max tree cover problem, which can be used to obtain a 16-approximation algorithm for HAPP.

Conclusion and References

- Robust adaptive allocation of tasks to agents that is resilient to agent failures.
- Polynomial time approximation algorithms with bounds on worst case performance that is irrespective of number of agents or tasks.
- Future work: Distributed algorithm to solve HAPP.
- Several works on paths for homogeneous agents to minimize min-max cost. We extend these works to task allocation to **heterogeneous** agents while **minimizing the maximum cost** of the path.

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