Swarm Intelligence for Agents in Smart Edge Environments

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Motivation. Smart devices, sensors, autonomous robots, drones, and other similar instruments have increasingly become pervasive in industrial and home environments, for numerous use-cases and scenarios. These devices are not limited to the acquisition of data as mere observers of their surroundings, but they are also capable of actuation, and of potentially complex processing of rapidly produced data flows. Given their limitations in terms of computational, storage, and power capabilities, some of these processing features can be delegated to intermediate edge nodes in a network of smart devices, integrated with cloud interactions when required. While in simple cases a manual and explicit set up of this infrastructure is possible, the reality is that more and more use-cases are subject to highly dynamic changes in the number and type of devices, as well as the nature of their interactions. Under these conditions it becomes necessary to use higher-level abstractions that allow the self-organization of smart devices, bringing intelligence to the edge nodes, and allowing the collaborative distribution of their computational tasks through swarm-inspired behavioral patterns.

Challenges and open issues. Considering the potential of swarm agents for self-organizing edge nodes and smart devices, we identify a number of relevant challenges:

- Heterogeneous agent knowledge: Multiple schemas and ontologies exist for representing sensor and IoT devices and data. Are these enough to allow self-organization? [1, 5, 2]
- Are there swarm-inspired models that can be propagated to smart edge agents? Can these act as mediators among devices according to their capabilities? [4]
- What is the role of social coordination of agents in a swarm environment? Can the Web serve as a common place to enable the establishment of inter-deployment knowledge exchanges? [8]
- Negotiation in the context of swarm agents can bring both advantageous optimization patterns, as well as delays and potential conflicts. It may become crucial to identify ways of reducing the risks, and to find compromises that adapt to changing situations and redefinition of goals. [7, 6]
- In this context the risks of manipulation and mischievous behaviors is more than plausible. The conception of integrity, confidence, and transparency mechanisms need to be integrated into this research road-map.
- Edge and sensing devices are often required to acquire and handle sensitive data, which should be subject to strict privacy constraints, while keeping the computation and processing goals. [3, 9]

Opportunities. Addressing these challenges, swarm intelligent agents for smart edge may open a number of research opportunities:

- Semantic representation of shared goals, organization patterns, and behaviors have the potential to facilitate agent coordination and negotiation in swarm smart edge environments.
- Implementation of low-code solutions can help abstracting the complexity of smart edge agents, and their deployment under heterogeneous conditions.
- Smart edge agents necessarily need to go well beyond the Web as a means to interact. Nevertheless, the Web offers a solid and standard mechanism to enable the interoperability, discovery, and accessibility among different swarms.
- Fully decentralized swarms of agents can make use of existing approaches for self-organization that have been successfully used in previous works in other contexts.
- Domain-specific deployments can help drive the requirements and implementation of this idea on different areas including automation, self-driving vehicles, robotics, domotics, eHealth, etc.
- Federated learning and decentralized processing can be adapted to run on swarm agents for smart

edge environments, further expanding their applicability.

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