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A UAV-enabled mobile edge computing paradigm for dependent tasks based on a computing power pool

Key words: Unmanned aerial vehicle (UAV); UAV-enabled mobile edge computing (U-MEC); Computing power pool; Dependency; Repeatability

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Motivation

1. The advent of the fifth-generation (5G) and sixth-generation (6G) wireless communication technologies has precipitated a proliferation of Internet of Things (IoT) devices and artificial intelligence applications. This has exerted considerable pressure on existing computing power networks.

2. Unmanned aerial vehicle (UAV)-enabled mobile edge computing (U-MEC) has been identified as a novel paradigm for responding to the proliferation of data. Notwithstanding, the discordance between the computing demands and the limited resources of UAVs poses a considerable challenge.

3. Several studies have been conducted on dependent tasks. However, most of these studies view the tasks in isolation, resulting in the inefficient use of scarce resources.

Main idea

1. The present study investigates a scenario where multi-UAVs assist multi-users in offloading dependent tasks comprising subtasks that are partly repetitive.

2. The proposed scheme involves establishing a computing power pool to facilitate task linkage. To address this issue, a two-stage alternative optimization method has been adopted.

3. A series of simulations have been conducted to analyze and evaluate the effectiveness of the proposed scheme as well as the impact of the subtask repetition rate.

System model

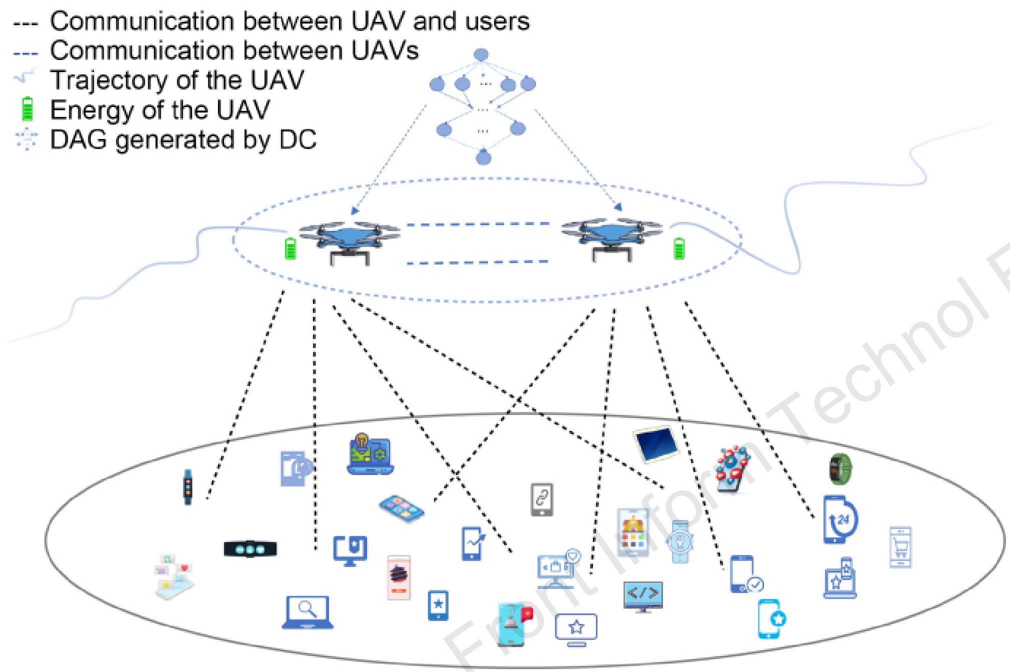

Fig. 1 System model (UAV: unmanned aerial vehicle; DAG: directed acyclic graph; DC: data center)

Multi-UAVs are employed to assist multi-users in offloading computationally intensive tasks. Following the collection of task specifications of M users by N UAVs, a provisional computing power pool is established to facilitate the execution of requisite computations.

Problem modeling and solving

The problem of balancing the energy consumption of UAVs is mathematically formulated through the joint optimization of the UAV–user association, communication resources, computing resources, UAV–subtask association, and the trajectories of UAVs, constrained by the demands of tasks and the capacity of UAVs. This problem is NP-hard.

Problem modeling and solving

A scheme based on constructing a computing power pool for task linkage is proposed to solve it. Accordingly, the original problem is disassembled into two subproblems, i.e., the optimization of UAV–user association, communication resource allocation, and UAV trajectory, and the optimization of UAV–subtask association and computational resource allocation. We adopt a two-stage alternate optimization algorithm based on successive convex approximation (SCA) technology and an improved genetic algorithm (GA) through operator redesign to solve this problem.

Major results

Effect of the number of users on energy consumption, time, and computing pool construction

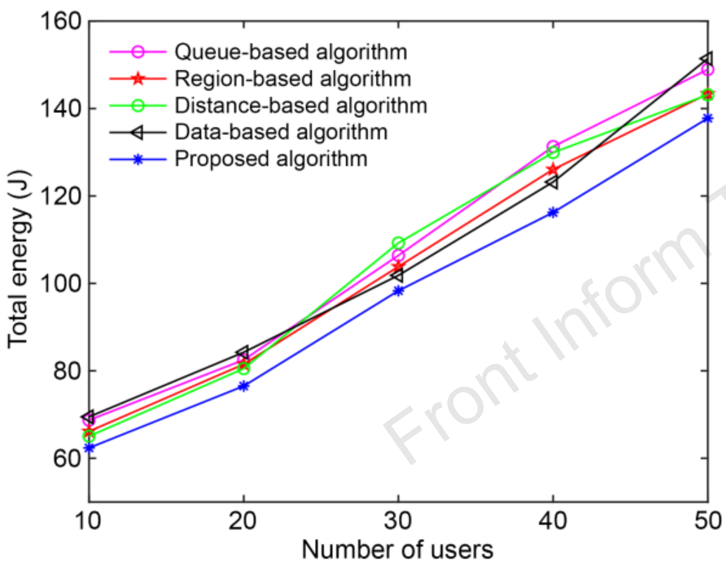

Fig. 2 Total energy consumption for different numbers of users

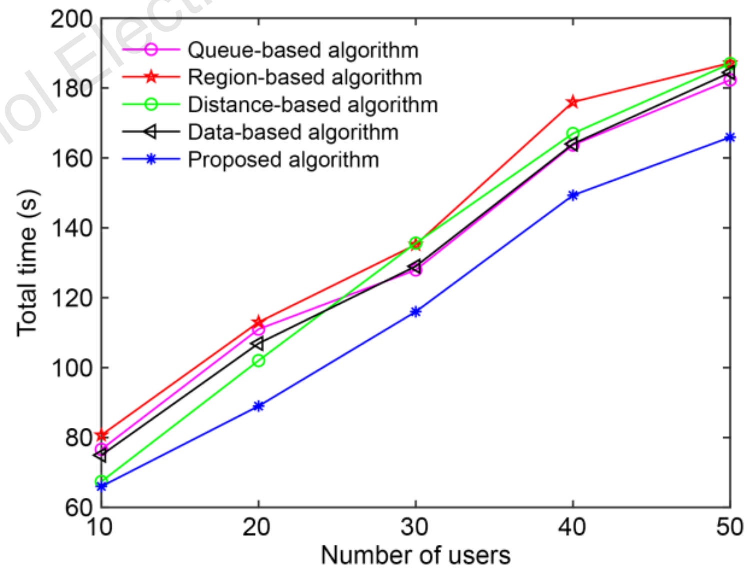

Fig. 3 Total time consumption for different numbers of users

Major results

Changes in energy consumption and time as the number of users increases

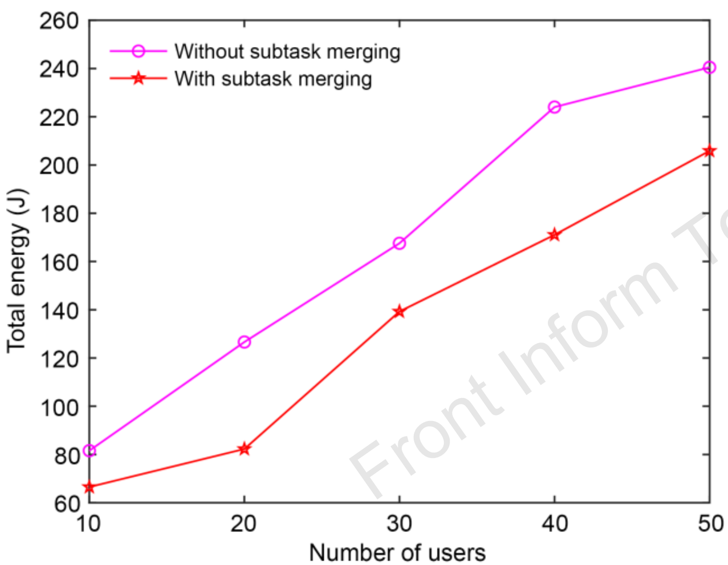

Fig. 4 Changes in total energy consumption of different numbers of users

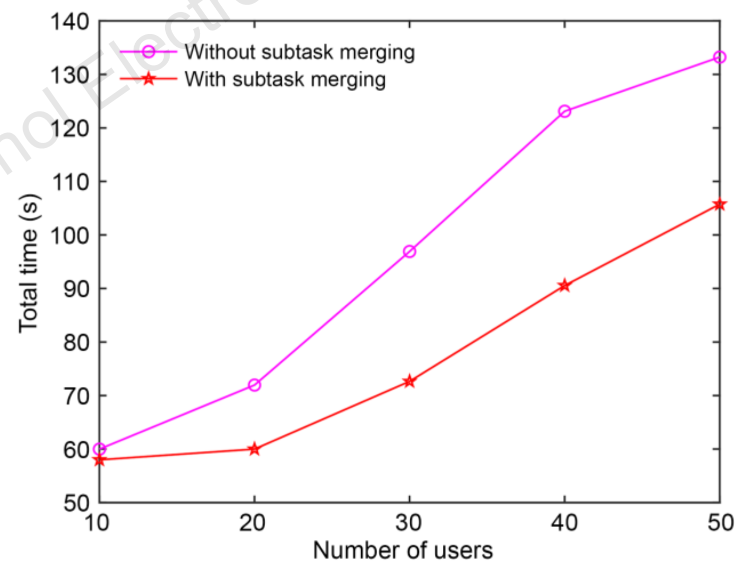

Fig. 5 Changes in total time consumption of different numbers of users

Major results

Changes in energy consumption and time with an increasing average number of repetitions.

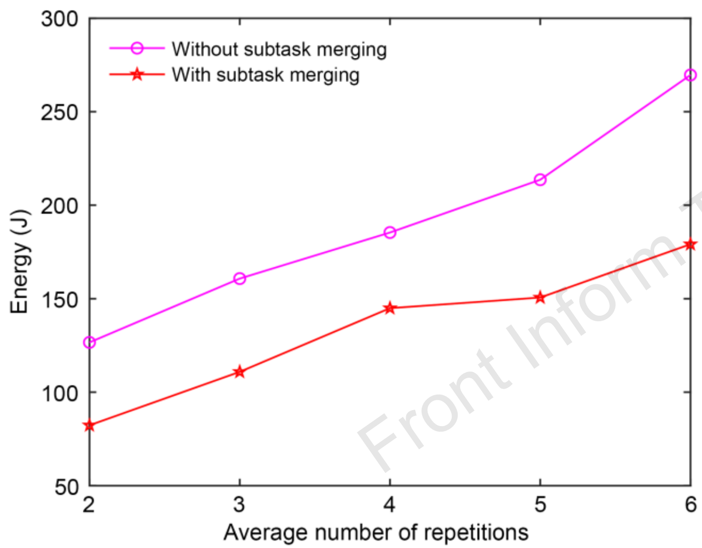

Fig. 6 Changes of energy consumption under different average numbers of repetitions

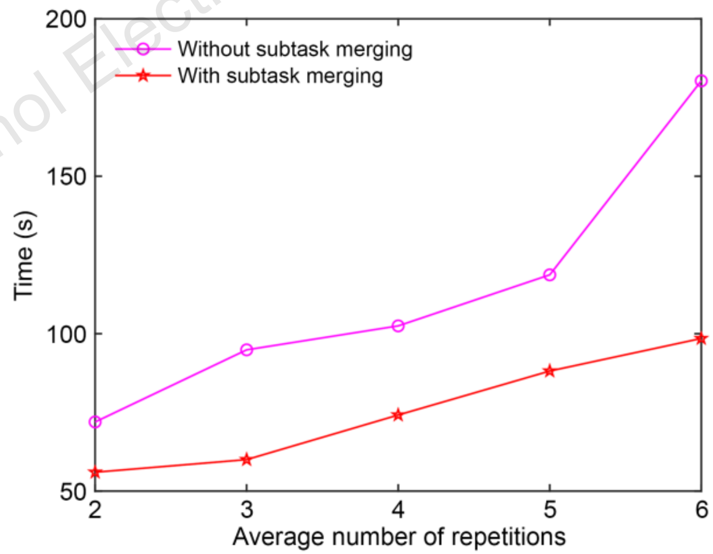

Fig. 7 Changes of time consumption under different average numbers of repetitions

Conclusions

1. The proposed method can effectively enhance the efficiency of UAV task processing. On average, the execution time was reduced by 18.41% and the energy consumption by 21.68%.

2. Furthermore, the proposed method showed remarkable efficacy in reducing task processing time and energy consumption as the number of subtask repetitions increased. Compared to the scenario without repetitive task processing, the execution time increased at a gradual rate, with a reduction in growth of 11.57 percentage points. Energy consumption was also reduced by 57.63 J on average.

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