International Journal of Digital Crime and Forensics
Volume 16 • Issue 1 • January-December 2024

Efficient Task Offloading for Mobile Edge Computing in Vehicular Networks

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ABSTRACT

In vechcular networks, a promising approach to enhance vehicle task processing capabilities involves using a combination of roadside base stations or vehicles, there are two challenges when integrating the two offloading modeth: 1) the high mobility of vehicles can easily lead to connectivity interruptions between nodes, which in turn affects the processing of the tasks that are being offloaded; and 2) vehicles on the road are not completely trustworthy, and vehicle tasks that contain private information may suffer from result errors or privacy leakage and other problems. This paper investigates the computing offloading problem for minimizing task completion delay in vehicular networks. Specifically, we design a trust model for mobile in-vehicle networks and construct a migration decision problem to minimize the overall delay of task execution for all vehicle users. The simulation results show that the scheme proposed in this paper can effectively reduce the execution delay of the task compared to the baseline scheme.

KEYWORDS

Computing Offloading, Resource Allocation, Trust Model, Vehicular Edge Computing

With the rapid development of new technologies such as autonomous driving and in-vehicle communication, application services that require high computing power or have high latency requirements are widely used in in-vehicle networks, including autonomous driving (Ren et al., 2020; Zhu et al., 2023; Zhou et al., 2019) intelligent traffic control (Xu et al., 2023) and image- or video-assisted real-time navigation (Fan et al., 2023). However, the limited computational resources of vehicles seriously hinder the realization of the above applications, and it is difficult to achieve good performance by relying only on the vehicle itself (Gao et al., 2023); thus, edge computing is regarded as a promising approach (Chen et al., 2023). By utilizing edge computing technology, vehicles can offload the complex computational tasks of applications to platforms with more resources, thus shortening the response time of applications and improving the service quality of applications. When there are multiple resource-rich edge nodes in a network, choosing which edge node to offload the task becomes the primary problem to be solved by the vehicle. Currently, there are two approaches for solving this problem: roadside server-assisted migration and road vehicle migration.

DOI: 10.4018/IJDCF.349133

For the first approach, the vast majority of research has focused on server-based migration strategies, and the more common scheme is to achieve migration based on the distance of the requester or node availability. Zhu et al. (2023) considered the constraints of service latency as well as the quality of the task and used the binary particle swarm optimization method to construct a task offloading scheme. Similarly, Hou et al. (2020) introduced partial offloading and redistribution mechanisms into the regular offloading process, using heuristics to maximize reliability under delay constraints. Fan et al. (2023) further refined the task offloading process through collaboration between edges to achieve balanced computational loads in the network. Lin et al. (2020) added an authentication mechanism to ensure security during the migration process.

Due to facility costs, it is impractical to deploy servers along all highways. To address this lack of infrastructure, using other vehicles to achieve task offloading has become an effective approach (Ma et al., 2021). Shi et al. (2020) provided a dynamic pricing scheme that optimizes the gains of vehicles to achieve the migration of computational tasks between vehicles through a deep reinforcement learning approach. Fan et al. (2023) proposed a heterogeneous migration scheme that uses both vehicles and edge servers to achieve migration. Chao et al. (2019), Hou et al. (2020) and Lin et al. (2020) introduced parked vehicles as nodes into the network. Fan et al. (2023) and Xue et al. (2023) utilized parked vehicles as forwarding relays to expand the service range of mobile vehicles as well as edge servers, which minimized the processing delay of weighted tasks within the system. Shi et al. (2020) and Fan et al. (2022) then formed computing clusters of parked vehicles to participate in the task offloading process. Fan et al. (2023) and Dai et al. (2019) utilized only vehicles waiting for traffic lights as temporary computing nodes to assist in migration.

However, problems still exist for in-vehicle network task migration. First, existing task offloading research has mainly focused on offloading between vehicle nodes and roadside base stations or vehicles, and it is rare to consider both offloading modes at the same time. Considering two offloading modes further increases the complexity of the migration decision problem. Second, the above work mostly assumes that the devices in the network are trustworthy, and any node can perform task offloading. However, in an open network environment, malicious nodes are inevitable. These malicious nodes could steal private information or interfere with task offloading. When tasks are offloaded to malicious nodes, the accuracy of task results cannot be guaranteed. Although the traditional authentication system can guarantee the security of task offloading in vehicular networks to a certain extent, it is difficult to filter for malicious nodes with legitimate identities within the network. Constructing trust relationships between nodes in a network is a challenging problem. To address the above issues, we propose a trusted and efficient task offloading scheme for vehicular networks, and our contributions are summarized as follows.

In this paper, we consider a hybrid migration scenario in which computational tasks can be migrated to edge servers as well as road vehicles and design a node trust value evaluation model considering the impacts of vehicle mobility.

In this paper, four parameters – internode transmission delay, network communication link stability, trust assessment, and computation delay – are combined to model the trusted computing offloading problem of service nodes in a vehicle network, and an offloading strategy decision problem with average delay minimization, link stability, and trust assessment maximization is constructed.

We analyze the complexity of the above problem and then design an algorithm based on an alternating direction method of multipliers (ADMM) and a convex difference algorithm to find a set of approximate solutions. Simulation experiments show that the proposed scheme in this paper can effectively reduce task delay and improve service quality.

SYSTEM MODELLING

In this paper, we provide mobile edge computing services to users in a time-varying vehicular network, as shown in the scenario in Figure 1. Mobile vehicles with spare computing resources and