

Joint optimization of Smart Sensing RIS-equipped V2X Hybrid Computation Offloading for Beyond 6G Communication

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Abstract

The Internet of Vehicles (IoV) needs significant computational resources to meet latency demands, still, traditional edge computing struggles with the growing number of vehicles and their computational needs. Vehicular Edge Computing (VEC), which uses resources at Road Side Units (RSUs) and within vehicles, offers a solution by offloading tasks to reduce latency. However, optimizing offloading is complicated by the dynamic nature of C-V2X communications. To address these issues, Reconfigurable Intelligent Surfaces (RIS) are proposed to integrate with the VEC systems to improve communication reliability and coverage, optimizing the wireless environment for vehicles. The proposed C-V2X-based RIS Smart Sensing Hybrid Offloading strategy combines VEC and RIS technologies to enhance performance, reduce latency, and improve safety in intelligent transportation systems. The result shows that the proposed algorithm can improve the system performance and further minimize the latency.

I. Introduction

The Internet of Vehicles (IoV) confronts notable hurdles, including the need for ample computational resources to fulfill latency demands for intelligent transportation services [1]. With a surge in vehicle numbers and heightened computational requisites, conventional edge computing struggles to suffice. Vehicular Edge Computing (VEC), a form of Mobile Edge Computing (MEC) tailored for vehicular environments, emerges as a viable remedy, harnessing computing capabilities at Road Side Units (RSUs) and within vehicles themselves [2]. Through a multi-tier VEC system, tasks can be offloaded to VEC servers or fellow vehicles, thereby reducing computing service latency and ensuring the safety of intelligent transportation systems. However, optimizing offloading strategies within VEC encounters challenges, particularly in navigating the nuances of the C-V2X link. Under the C-V2X architecture, vehicle sensing encounters instability [3] due to rapid topology changes, complicating the modeling of successful transmission probabilities for Vehicle-to-Vehicle (V2V) links. Moreover, the distinctive attributes of PC5 and Uu interfaces further complicate the joint optimization of offloading strategies and resource allocation.

While VEC systems already leverage computing resources within vehicles and RSUs to optimize tasks and reduce latency, integrating Reconfigurable Intelligent Surfaces (RIS) technology can further enhance communication reliability and coverage. By strategically deploying RIS elements along roadways or within urban environments, VEC systems can optimize

the wireless communication environment for vehicles, leading to improved system performance and enhanced safety in intelligent transportation systems. In this work, a C-V2X-based RIS Smart Sensing Hybrid Offloading strategy is proposed to address the challenges encountered in vehicular communication systems. This innovative approach integrates the capabilities of VEC with RIS, aiming to optimize communication reliability and coverage. The instability of the C-V2X link and the complexities in modeling successful V2V transmissions are addressed by strategically deploying RIS elements. By leveraging both VEC and RIS technologies, system performance and safety in intelligent transportation systems are enhanced, offering a promising solution to the evolving demands of the Internet of Vehicles.

II. Proposed System and Problem Formulation

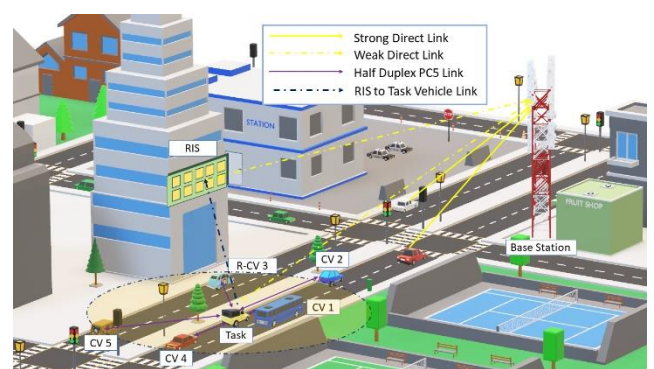


Figure 1. Proposed V2x-RIS Sensing Hybrid Computation Offloading

In the proposed V2X-RIS system, multiple vehicles and a single RSU connected to VEC servers are depicted in Fig. 1. There are three

types of vehicles: task-based vehicles (TVs), which generate tasks based on vehicle communication, RIS equipped cloudlet vehicle (R-CV), and cloudlet vehicles (CVs) denoted as $\mathcal{K} \in \{1, 2, \dots, K\}$. The system includes MEC and CVs, with TVs exchanging data with RSUs and CVs via the Uu and PC5 interfaces, respectively. This study considers partial offloading which can be divided as TV sending a portion of the task to RCV and CV, and the other portion to the VEC server. Due to the complexity of algorithm, this study consider uplink optimization while downlink is omitted because of high power of RSU.

$$\min_{p^{Uu}, \lambda, f_{ser}^{veh}, \varepsilon} \sum_{l=1}^L \max\{T_l^{ser-o} + T_l^{ser-c}, T_{l,k}^{veh-o} + T_{l,k}^{veh-c}\}$$

s.t. ~ C1, C2, C3, C4, C5, C6, C7

where p^{max} denotes the TVs power constraint, and $\lambda^{max} = N_{frame}$ indicates the maximum packet transmit frequency of the PC5 interface. Additionally, f_{ser}^{max} and $f_{ser}^{veh,max}$ denote the maximum computation frequencies of the VEC server and the k-th CV, respectively. Constraint C1 : $\sum_{l=1}^L p_{l,K+1}^{Uu} + p^{PC5} \leq p^{max}$ represents total power for uplink is less than maximum vehicle power. Constraints C2: $L_l \lambda \leq C_{v2v}^{max}$ and C3: $\lambda \in (0, \lambda^{max}]$ guarantee the packet frequency will be lower than channel capacity. Constraints C4: $\sum_{l=1}^L f_l^{ser} \leq f_{ser}^{max}$ and C5: $\sum_{l=1}^L J(\varepsilon_{l,k}) f_{l,k}^{veh} \leq f_k^{veh,max}$, $\forall n \in \mathcal{K}$ forcing the CPU allocation is less than maximum vehicle's computation power. Constraint C6: $\varepsilon_{l,k}, \varepsilon_{l,K+1} \in [0, 1]$, $\forall n \in \mathcal{K}$ and C7: $\varepsilon_{l,K+1} + \sum_{k=1}^K \varepsilon_{l,k} = 1$, $\forall n \in \mathcal{K}$ ensures that the total partial offloaded task is normalized value and equal to 1.

III. Result

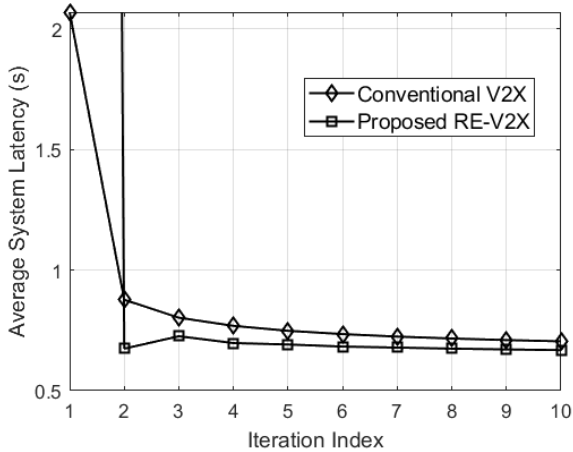


Figure 2. Convergence rates of proposed RE-V2X latency in seconds.

In this section, a simulation result of proposed RE-V2X is obtained through computer simulation. Following C_m is random uniform $U[.,.]$ with value $U[500,1000]$, $f_{max}^{veh} = U[1,2]$ GHz, number of task $M = 10$, number of cloudlet vehicle $N = 15$, $P_{max} = 23$ dBm, and noise -70 dBm. Fig. 2 depicts that the proposed algorithm achieved convergence for iteration 3. Moreover, it outperforms the conventional V2X offloading with no RIS.

IV. Conclusion

This study proposed a novel solution for V2X offloading by employing R-V2X and RIS to improve latency. In contrast with other studies, R-V2X shows a better latency because of flexible placement of R-CV that can enhance sensing and packet transmit probability. The results show that both latency and convergence rates is better than conventional V2X based offloading, and potentially can be utilized for beyond 6G communication. To enhance current works, a recent technique related to distributed task offloading is appealing for future works, since it has capability to solve a task if there is no BS coverage.

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