Optimizing the System Utility of Vehicles in Vehicular Ad Hoc Network

[1]Pyae Sone Aung, [2]Choong Seon Hong
Department of Computer Science and Engineering, Kyung Hee University
Yongin, 446-701 Korea
{[1]pyaesoneaung, [2]cshong}@khu.ac.kr

Abstract

The growth of computation intensity of applications implemented on vehicles makes it quite challenging to overcome the balance between not only the capability but also the performance. In this paper, we propose the scheme where the vehicles try to offload their computation tasks while in range of the vehicular edge computing (VEC) server. The overall system utility of the vehicles for the workload computation time in vehicular ad hoc network is maximized with adjustment between offloading ratio to the vehicular edge computing server and computation resources of the vehicles. We formulate the optimization problem and solve it using the Kullback-Leibler divergence algorithm. Our simulation results indicate that our proposed method provides significant results in system utility.

1. Introduction

Nowadays massive development in the fields of Internet of Things (IoT) and future 5G network leads the vehicular networks into Vehicular Ad Hoc Networks (VANETs). Vehicles now become intelligent machines as they can drive autonomously, and are implemented with smart infotainment and entertainment systems that are able to perform based on specified user's preferences [1]. As a result, vehicles are required to achieve highly reliable connections due to emerging services such as exact 3D map navigation, video streaming and traffic reports between the vehicles to vehicles (V2V) or vehicles to infrastructure (V2I).

The aforementioned services, such as infotainment, video streaming and so on, require extensive computation resources to process a huge amount of workload data and have low latency requirements. These large volume of workload cannot be handled alone by the vehicles and need to be offloaded to the vehicular edge computing (VEC) server which may be road site unit (RSU). However, to determine which portion of workload to compute locally and how much computation resources to be used, while maintaining minimal delay, is also a problem. In this paper, we try to optimize the overall system utility of vehicles while determining the optimal portion to offload the computation tasks balancing the computation resources.

The contributions of this paper can be summarized as followings:

- We propose the scheme where vehicles try to offload tasks to the VEC server and formulate system utility function of the vehicles considering the offloaded tasks and computation resources of the workloads.
- We transform the problem and solve by using Kullback-Leibler divergence to balance between the offloaded portion and computation resources of the vehicles.
- The simulation results demonstrate that the overall system utility does not deteriorate much as the number of vehicles increases.

2. System Model and Problem Formulation

The system model is shown in Figure 1, where we consider the road area in which the

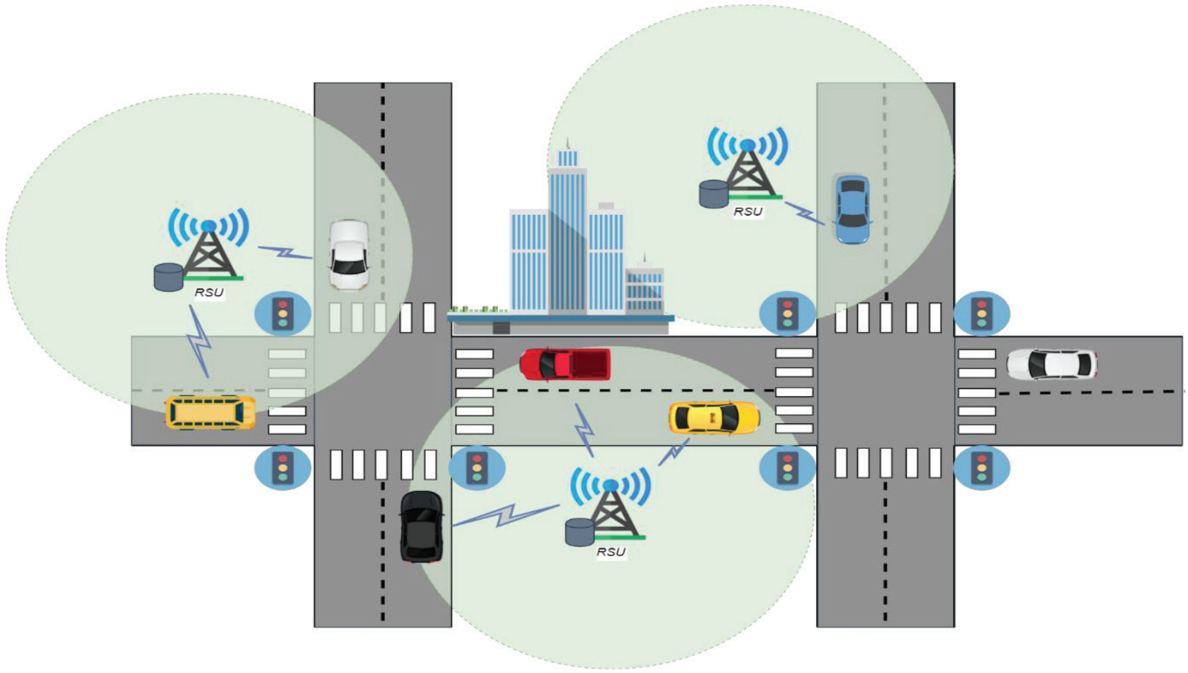

Figure 1 System Model

RSUs $\mathcal{R} = \{1,2,\dots,R\}$ are located and each RSU is implemented with the VEC server. We assume that the vehicles, $\mathcal{V} = \{1,2,\dots,V\}$ are arriving at uniform rate with constant speed. We assume each vehicle have some workloads, $I \in \mathcal{V}$, which may be video streaming or real-time traffic navigations, that need to be offloaded to the VEC server while in range of the RSU. Therefore, the time required for the computation of the tasks for each vehicles is as follows.

$$T_v = \frac{\beta_v I_v}{f_v} \tag{1}$$

where β is the workload ratio variable of the offloading data which is in the range between 0 and 1, I is the workload data size and f_v is the computation resource of each vehicle. The utility of each vehicle can be expressed as the logarithmic function known as proportional fairness function [2] used to obtain load balancing and can be defined as follows [3].

$$U_v = \rho \ \log(1 + \sigma - T_v) \tag{2}$$

where ρ is the satisfaction parameter and σ is to normalization parameter so that the satisfaction does not reach negative value.

Our goal is to maximize the vehicles' utility and can be formulated as follows.

$$\max_{\boldsymbol{\beta},\mathbf{f}} \quad \sum_{v=1}^{V} U_v \tag{3}$$

$$s.t \quad T_v \leq T_{max} \tag{3a}$$

$$0 \leq \beta_v \leq 1 \tag{3b}$$

$$f_v \leq F_{max} \tag{3c}$$

where constraint (3a) is that the vehicle can be offloaded when only in the range of the RSU. Constraint (3b) is that the offloading ratio variable is only between 0 to 1 and the constraint (3c) is for the maximum available computation resources of the vehicle.

3. Problem Transformation

Our optimization problem (3) is now in the form, $U_v = \rho \ \log(1 + \sigma - \frac{\beta_v I_v}{f_v})$. We transform this problem into the Disciplined Convex Programming (DCP) format. Due to the limitation of the paper, the detailed transformation is omitted. The transformed problem can be written as follows.

$$\max_{\boldsymbol{\beta},\mathbf{f}} \sum_{v=1}^{V} \left(-\rho \log\left(\frac{\rho f_v}{\rho f_v(1+\sigma)-\rho\beta_v I_v}\right) + \rho - \rho f_v - \rho f_v \sigma + \rho\beta_v I_v\right) \qquad (4)$$

(3a), (3b), (3c)

The objective function is now in the form of DCP and can be solved by utilizing Kullback-Leibler divergence function from the CVXPY [4][5].

4. Simulation Results

We consider the area where the number of RSU is 3, each equipped with a VEC server. We assume the workloads date size of each vehicle are random between 40 to 150 Mb. We tested with 10 vehicles increasing up to 40 vehicles. As shown in Figure (2), according to our simulation results, the system utility does not deteriorate much even due to the increase in the number of vehicles.

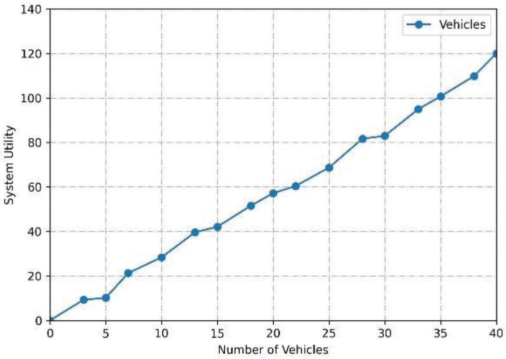

Fig. 2. System Utility with Increasing Number of Vehicles

5. Conclusion

In this paper, we consider the vehicular ad hoc network where vehicles try to offload some of the tasks to the VEC server. We propose the optimization of the utility of the system while balancing between the offloading portion ratio and computation resources of the vehicles. Our simulation results present that the optimized system utility does not increase much even with the increasing number of the vehicles in the area.

Acknowledgement

This work was supported by Institute of Information & Communications Technology Planning & Evaluation(IITP) grant funded by the Korea government(MSIT)(2020-0-00364, Development of Neural Processing Unit and Application systems for enhancing AI based automobile communication technology) *Dr CS Hong is the corresponding author.

References

[1] Aung, Pyae Sone, Kyi Thar, Anselme Ndikumana, and Choong Seon Hong. "Smart Information Service Management for Public Transportation." 한국정보과학회 학술발표논문집 (2019): 418-420.

[2] Li, Li, Martin Pal, and Yang Richard Yang. "Proportional fairness in multi-rate wireless LANs." In IEEE INFOCOM 2008-The 27th Conference on Computer Communications, pp. 1004-1012. IEEE, 2008.

[3] Dai, Yueyue, Du Xu, Sabita Maharjan, and Yan Zhang. "Joint load balancing and offloading in vehicular edge computing and networks." IEEE Internet of Things Journal 6, no. 3 (2018): 4377-4387.

[4] Diamond, Steven, and Stephen Boyd. "CVXPY: A Python-embedded modeling language for convex optimization." The Journal of Machine Learning Research 17, no. 1 (2016): 2909-2913.

[5] Agrawal, Akshay, Robin Verschueren, Steven Diamond, and Stephen Boyd. "A rewriting system for convex optimization problems." Journal of Control and Decision 5, no. 1 (2018): 42-60.