A Sensing Data Collection Strategy in Software-Defined Mo-bile-Edge Vehicular Networks

Lionel Nkenyereye, Jong-Wook Jang

Abstract*: The car is seeing as an intelligent transportation sensing platform suitable to transfer wirelessly urban sensing data to a remote processing server. This paper comes out with the study on urban sensing data collection strategy in a Software-Defined Mobile Edge vehicular net-working. The two schemes for data collection in urban using a car are cooperative vehicular and edge cell trajectory prediction mode. In cooperative vehicular scenario, the vehicle observe its neighboring vehicles and sets up vehicular cluster for cooperative sensing data collection. The data collection output can be transmitted from vehicles participating in the cooperative sensing data collection strategy to the vehicle on which the sensing data collection request originate through V2V communication. The vehicle on which computation originate will reassemble the computation output and send to the closest RSU. In case the neighboring vehicles are unable to handle the urban sensing request, the edge cell trajectory prediction decision based on the SDEVN architecture is selected. The SDEVN (Software Defined Edge Vehicular Network) Controller determines how much effort the sensing data collection request requires and calculates the number of RSUs required to support coverage of one RSU to the other. Thus, The RSU which extracts resources level and location information, then send that information to the SDEVN controller to compute the movement trajectory of the neighboring's vehicles. The SDEVN forecasts and determines the position and then allows reconnection to the following RSU of each vehicle. The goal is to maximize the number of vehicles that participate in executing a sensing data collection request (task) which consisting in sensing the environmental conditions towards vehicle's destination. We prove that urban sensing data collection cost through a car sensing platform for urban data collection algorithm to find an optimal strategy. We set up a simulation scenario based on realistic traffic and communication features and demonstrate the scalability of the proposed solution. The proposed vehicular architecture is based on the edge cell which includes RSU, RSU controller, and SDEVN controller, represent the first comprehensive vehicular ad hoc computing (VANET) implementing based on Software defined mobile edge vehicular network concept..

***Index Terms*: Software-Defined Networks, Software-Defined Mobile Edge computing, sensing data collection, car as urban sensing platform, Vehicular ad hoc networks, optimal strategy, Edge computing**

Revised Manuscript Received on December 22, 2018.

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I. INTRODUCTION

A wide range of applications are proposed since the car is seeing as an urban sensing platform. The car has for long time used as single sensing probe where in-vehicles sensing data collected through different sensors embedded in the vehicle. These sensors exchange data through a technology called Control Area Network (CAN) [1]. Since the digital communication between vehicles and fixed infrastructures has been implemented, a vehicle can exchange information with others through Vehicle-to-Vehicle communication (V2V) or vehicle-to-infrastructures (V2I) like Road Side Units (RSUs).This means, the vehicle needs to have access to road infrastructures through RSUs using infrastructure based communications (hereafter V2I) [2]. In fact, V2I communications allows vehicles to communicate to RSUs through Dedicated Short Range Communications (DSRC). Furthermore, RSUs forward received messages to central Intelligent Transportation System (ITS) applications servers by exploiting wide area networks [2]. The car has the potential to contribute on the development of smart cites by accessing urban data that are collected and reported to a remote data center through wireless communication.

Software Defined Network (SDN) and fog computing [3] [4] are emerging technologies in information and communication tech-nology to minimize data collection latency in Internet of Vehicles (IoV) [5]. These technologies lead the authors of this paper to propose a novel sensing data collection strategy schemes. The SDN is a growing computing and networking concept that has implicit ability to associate V2I and VANETS [9]. SDN separates control plane and data plane entities. It executes the control plane software on general purpose hardware. SDN permits self-supported deployment of control, traffic forwarding and computing devices. Fog computing relays on the use of network and hardware virtualization concept to provide computation, storage, and networking services between subscribers' devices and existing cloud computing data centers. Nonetheless, fog network comports several devices that are considered to use a lower computation power in general. Therefore, one standalone device may demand an excessive amount of resources to effectively terminate a request. In fact, it is workable to execute computing tasks in fog network in distributed configuration with enough computation resources and network virtualized functions (NVFs) [6].

This paper presents the study on urban sensing data collection strategy in a Software-Defined Mobile Edge vehicular networking.

The two sensing data collection schemes are cooperative vehicular and edge cell trajectory prediction mode. In cooperative vehicular strategy, the vehicle observe its neighboring vehicles and sets up vehicular cluster for cooperative sensing data collection. The data collection output can be transmitted from vehicles participating in the cooperative sensing data collection strategy to the vehicle on which the sensing data collection request originate through V2V communication. The vehicle on which computation originate will reassemble the computation output and send to the closest RSU. The SDEVN (Software Defined Edge Vehicular Network) Controller determines how much effort the sensing data collection request requires and calculates the number of RSUs required to support coverage of one RSU to the other. In case the number of RSU required is more than 1 or probability a neighboring car not to finish the urban sensing request, SDN edge cell trajectory pre-diction decision is selected. Thus, The RSU extracts resources level of neighboring vehicles and location information, then send that information to the SDEVN controller to compute the movement trajectory of the candidate's vehicles. The SDEVN forecasts and determines the position and then allows reconnection to the following RSU of each vehicle. The goal is to maximize the number of vehicles that participate in executing an urban sensing data collection request (task) which consisting in sensing the urban environmental conditions towards vehicle's destination.

II. BACKGROUND

In this section, we briefly introduce the Software-Defined Mobile Edge vehicular network.

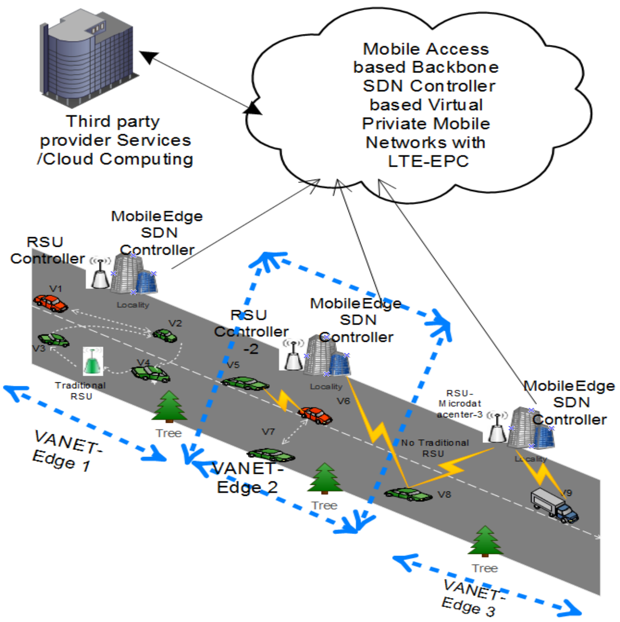

Figure 1. Topology structure of Software-Defined Mobile Edge Vehicular Network

Based on the Figure 1, Software-Defined Mobile Edge vehicular network has several VANET-edge infrastructures. The VANET-edge 1 has big advantages in LTE for V2V before D2D LTE enables vehicles to communicate their geospatial coordinates to each other directly when in low-or no-connectivity range up to 100 meters. However, in VANET-edge 3, the restricted coverage issue is susceptible because of deficient RSUs. On the other hand, the wired network, that operates as backbone network would provide a higher volume of sensing data collected by vehicles and in turn transferred to the cloud computing for further processing insights.

Unfortunately, in a pure network, the network traffic of data transmission is defined to last an unbearable processing time be-cause of distance between a vehicle and cloud computing. To overcome the above issue, the edge computing technology has been presented to dive into an approach which decreases the overall delay due to the distance between the vehicle and the remote data center processing. Edge computing is a defined as a network of small scale data centers that store or aggregate data locally and push at demand received data to a cloud storage repository. In Edge computing, the cloud computing resources and storages are discovered at the edge of the vehicles networks and are close to the vehicles.

Since the applications are deployed on the edge computing ma-chines, the edge computing server is installed along with the road Mobile Edge SDN Controller in this paper. The Mobile Edge SDN enabling SDN technology. T.Nguyen et al. [7] shows that SDN, if applied to VANET can provide adjustable, programmability and go in for new services. The SDN controller in Mobile Edge SDN performs the overall of the vehicles pass by the RSU controller. Therefore, Mobile Edge SDN based SDN is treated as data plane but stationary.

III. URBAN SENSOR DATA COLLECTION SCHEMES IN SOFTWARE-DEFINED MOBILE EDGE VEHICULAR NETWORK

A. System Model of the car as an urban sensing platform

In this section, we are presenting characteristics and information about all vehicles. We consider that the vehicle is capable of determine its position. The determination is its position is fulfilled by GPS receivers [4].

We consider (x_a, y_a) location for a^{th} vehicle. Let v_a be the a^{th} vehicle from all vehicles A^{area} in a given area. Then we describe such set as $A^{area} = \{v_0, v_1, v_2, \dots, v_a, \dots, v_{A-1}\}$, where $a \in \langle 0, A-1 \rangle, a \in \mathbb{N}, A \in \mathbb{N}$

We assume that each vehicle v_a has a certain number of characteristics such as acceleration, speed, and General Resources (Input/output operations, storage, cache space, and network) GN and vehicles

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sensors the speed $speed_a$ is a speed of a^{th} vehicle at a particular time. The acceleration $accel_a$ is an acceleration of a a^{th} vehicle, determines how fast the velocity of an object divided by the time.

Let us consider another important characteristics of a^{th}vehicle 'sensors matrixA_a^{1xK}. This means that the matrix is controlling all information about vehicle's sensors. The next paragraph will explain the model of head sensing vehicle.

The head sensing vehicle. When it receives the sensing request by the nearest RSU. The RSU sends a beacon information that includes the following information: type of sensing data request, duration of urban sensing request, data sensing strategy. The head vehicle will generate packets to be executed by neighbor vehicle in case of data sensing strategy is cooperative vehicle strategy. On the contrary, SDN edge cell trajectory prediction decision is selected. The selection of the data sensing strategy depend on duration the urban sensing task will last

Let x_i be the i^{th} requested urban sensing task in a list of urban sensing request R^{tasks} , such list we would define $R^{tasks} = \{x_1, x_2, \dots, x_i, \dots, x_I\}$, where $i \in \langle 1, I \rangle, i \in \mathbb{N}, I \in \mathbb{N}$

Let r_i be the i^{th} current performance resource level in a list of performance resource levelP^{level}, then such list we have $P^{level} = \{r_1, r_2, \dots, r_i, \dots r_I\}$ where $i \in \langle 1, I \rangle, i \in \mathbb{N}, I \in \mathbb{N}$

We have already described a head sensing vehicle in a given area. The neighbor vehicle is a kind of vehicle that is within a communication range of the head sensing vehicle and V2V communication capability. A candidate neighboring vehicle means neighboring vehicles participate in urban sensing request due to their availability and sufficient performance resource level. They hold this status until the data collection of the sensing task reach the final destination which may be either the head sensing vehicle or the nearest RSU located near the urban sensing request is completed depends on the duration and the sensing strategy defined earlier in this paper. So in order to reach some destination vehicle, not only vehicle relay concept can be used but also the SDEVN architecture is an option to solve the issue of vehicle mobility.

We consider that all vehicles that come out after the head sensing vehicle start scanning are seeing as neighboring vehicles N^{neigh} . A neighboring vehicle selected as candidates to perform sensing task in cooperation with other vehicles will be candidate neighboring vehicles$C^{candneighb}$. Let v_j is a j^{th} neighbor vehicle from all neighboring vehicles in a given area A^{area} after the vehiclev_0. Let v_k is a k^{th} candidate neighboring vehicle from all candidate neighboring vehicle in a list of neighboring vehicles V^{neigh} in a given area.

$$C^{candneigh} = \{v_1, v_2, \dots, v_k, \dots, v_C\}$$

Where
$k \in \langle 1, N \rangle; k \in \mathbb{N}, C \in \mathbb{N};\ C^{candneigh} \subseteq N^{neigh};\ N^{neigh} \subseteq A^{area}$

The selection of candidate neighboring vehicles depend on the out**put** of probability to execute the urban sensing request**.** The head sensing v_0 vehicle is then adding to a set of candidate neig boring vehicles $N^{neigh} = \{v_1, v_2, \dots, v_j, \dots, v_N\}$ where $k \in \langle 0, N \rangle$.

Subsequently, for each v_j determine vehicle candidate probability $P_{cand} = (v_j, x_i)$ for participating in executing sensing request x_i with the highest performance resource PR_i . Also the total of resources consumption to complete the sensing task in the given duration consists of three phases: transmit performance resource level, execution of sensing request, send back the collected sensor data. It can be compute as

$$Reso_j^{TR}(v_j, x_i) = reso_j^{trx}(v_j, x_i) + reso_j^{exe}(v_j, x_i) + reso_j^{send}(v_j, x_i)$$
(1)

We will get a new cluster with neighboring vehicles, which values more or equal to minimal vehicle candidate probability vehicle candidate probability $P_{cand(v_j, x_i)}$ function.

Let $\emptyset_j^{PR}$ is the resource performance filter parameter of a neighboring vehicles for sensing requesti^{th}, if the total resource consumption for sensing request i^{th} will be less than the performance resource of sensing request i^{th} PR_i, the parameter $\emptyset_j^{PR}$ return 1, and otherwise zero. This function will assist us to not select neighboring vehicles that need more resources before fora a sensing requested is completed in the given duration of the sensing request.

$$\emptyset_j^{PR}(v_j, x_i) = \begin{cases} 1, if\ Reso_j^{TR}(v_j, x_i) < PR_i \\ 0, otherwise \end{cases} \quad (2)$$

Therefore, the vehicle candidate probability consists of one significant parameters, which collectively complement each other and are seeing as filter that help to determine the neighboring candidate vehicles to perform a sensing request. This is performance resource parameter $\emptyset_j^{PR}$,

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$$P_{cand}(v_j, x_i) = \emptyset_j^{PR}\ (v_j, x_i) \quad (3)$$

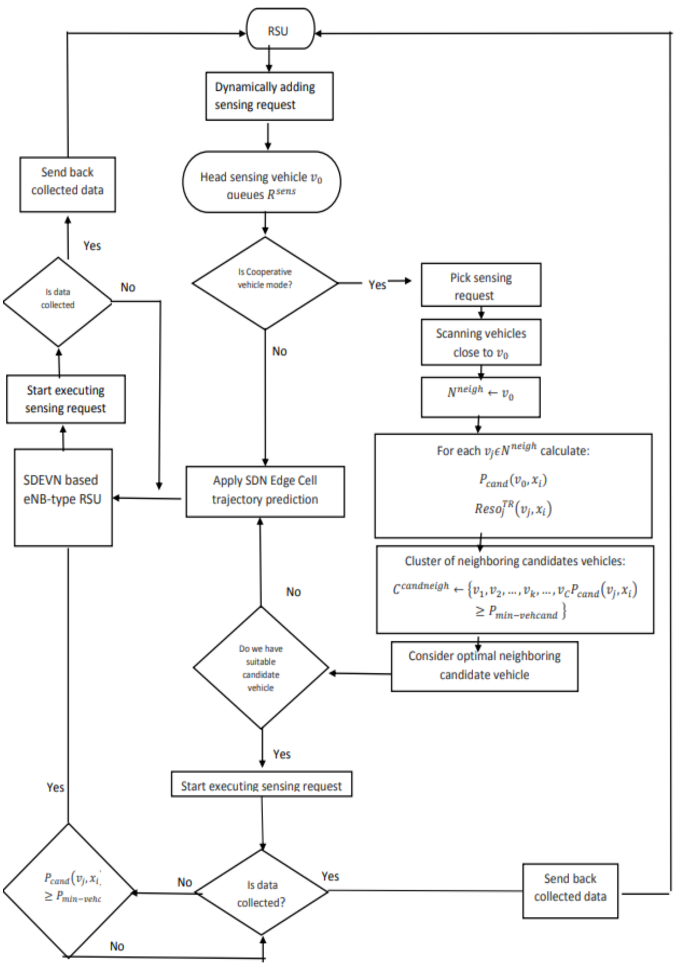

Figure 02. Flow Chart of the proposed Algorithm

Algorithm 1 car sensing platform for urban data collection algorithm

Input : $R^{tasks} = \{x_1, x_2, \dots, x_i, \dots, x_I\}$

Output : RSU adding sensing request x_i to vehicle v_j for collecting different type of data

1 **while** $R^{tasks} \epsilon \emptyset$ **do**

2 sensing request x_i is received by Head sensing vehicle v_0

3 **if** cooperative-vehicle mode **then**

4 v_0 extract instructions of x_i

5 scanning vehicles close to v_0, getting list N^{neigh}

6 $N^{neigh} \leftarrow v_0$

7 **for** each $v_j \ \epsilon \ N^{neigh}$ **do**

8 calculate $Reso_j^{TR}(v_j, x_i)$ using formula (1)

9 calculate $\emptyset_j^{PR}$ using () using formula (2)

10 calculate $P_{cand}(v_0, x_i)$ using formula (3)

11 **end**

12 $C^{candneigh} \leftarrow \{v_1, v_2, \dots, v_k, \dots, v_C | P_{cand}(v_j, x_i) \geq P_{min-vehcand}, C^{candneigh} \subseteq N^{neigh}\}$

13 **for** $C^{candneigh}$ **do**

14 v_k start collecting sensor data

15 **if** v_k finish collected data **then**

16 sent back collected data to v_0 or RSU

17 **else**

18 **if** $P_{cand}(v_j, x_i) \geq P_{min-vehcand}$ **then**

19 go to step #15

19 **else**

18 go to step 21

19 **end**

20 **else**

21 Apply edge cell prediction decision based on SDEVN architecture

22 starting collect sensor data

23 **if** v_k finish collected data **then**

24 sent back collected data to RSU

25 **else**

26 go to step 21

27 **end**

28 **end**

29 **end**

Figure 03. car sensing platform for urban data collection algorithm for the sensing data collection strategy in Software-defined Mobile edge vehicular network

B. car sensing platform for urban data collection algorithm

The flow chart of this algorithm is presented on the Figure 2.

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The pseudo code on the Figure 3In this subsection we overviewed the functional algorithm, just to understand high level concept of pro-posed method. We already know all parameters required to find optimal candidate neighboring vehicle execute some tasks with less resources

So let us imagine, in some area and head sensing vehicle starts to distribute sensing tasks. It can be any sensing tasks of updating or may be alerting that something happened on a road. Adding to this, urban road sensing request is to collect information about road condition, traffic conditions, weather information or taking picture or videos in certain area ahead to the driving destination

If we have no sensing request at the head sensing vehicle (or at the RSU infrastructure), the algorithm will check the beacon information every τ_1 millisecond until it receives the sensing request. We agree that at the time the RSU receive the request, it will broadcast to the near passing head sensing vehicles. The message is abstracted in a beacon information. We assume that the head sensing vehicle can accept to execute only one sensing request a time.

C. SDEVN architecture for trajectory prediction decision

The driving prediction parameter of vehicle during executing sens-ing task essential as long as it help for determining for a selected neighboring candidate vehicle how the vehicle will ride within the signal coverage range or what will happen when if any of neigh-boring candidates vehicles needs more resources to complete the sensing request or when there is no any optimal neighboring can-didates due to some case where they are busy or the resource are low to execute the sensing request. These assumptions leads us to the use of the SDN concept in VANETs by using the SDVN con-troller. The strategy is based on the SDN Edge cell trajectory (to-pology) prediction decision mode. The topology establishment is based on trajectory prediction with double purposes. The first purpose concerns the prediction the position of the vehicle and force the RSU to judge the accurate RSU where the next reconnection with the vehicle should occur. The next section presents the components of the proposed SDEVN controller.

D. SDEVN Controller

The Base station type-RSU hardware include the SDEVN control-ler. Hardware consists of a computing device and an OpenFlow Wi-Fi access point and switch. The software components on the computing device include the host operating system, a hypervisor, and an edge computing like Cloudlet in service of Virtual Machine VM. A hypervisor is a low-level middleware that enables virtualization [8] of the physical resources.

Based on this, we collaborate the SDN openFlow con-troller, SDN communication infrastructure controller and the active cloudlet controller to share information with each other to achieve a consistent view conditions about candidates neighboring vehicles. Specifically, when some the vehicle do not complete to collect urban sensing, the SDN openFlow controller will report them and related configuration to the SDN communication infrastructure controller and active cloudlet controller. Through this way, the SDN communication infrastructure controller maintains a table containing MAC and IP address of candidates neighboring vehicles cluster. The active cloudlet controller also maintain a table of RSU location information. In case of SDN edge cell trajectory prediction mode, the SDN communication infrastructure controller and SDN openFlow controller update the related information in proper time to guarantee they have a consistent view of the traffic and computing new routes without a re-initiation of new urban sensing request service in the RSU. Figure 4 shows how the consistent view about the SDEVN controller at the mobile edge network composed of e-NodeBase station (eNB) and RSU.

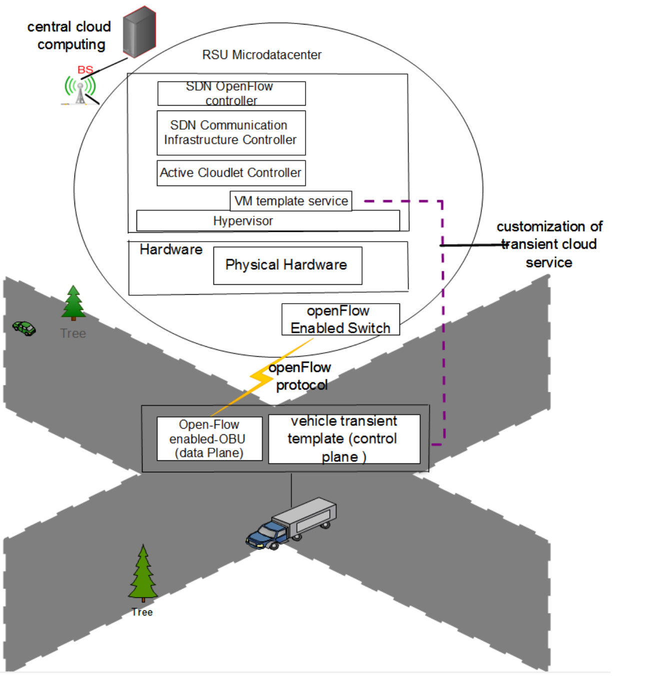

Figure 04 Components of the SDEVN controller for trajectory prediction

IV. EVALUATION

In this section, we analyze the simulation results to demonstrate the performance of our proposed car sensing platform for urban data collection schemes. We consider ten RSUs located along a grid road map equipped with one way roads and use Simulation of Urban Mobility to simulate the road traffic and OpenNet [9] The density of the vehicles on the road is set as l = 0.4. , Maximal speed is 50km/h. the performance resource decreases when a candidate neighboring vehicles is performing an urban sensing request. It gains it when is driving head or resting (no sensing receive from the head sensing vehicle).Candidate neighboring vehicle on which during execution of urban sensing task drop to the minimum level of performance resource must stop the current sensing request when this case happen. If this happen it will continue the sensing tasks assign until the urban sensing request is finished or when its level of performance resource is below to the critical threshold. The success of an urban sensing data collection tasks of these vehicles are grouped into five modes with the probabilities {0.04, 0.15, 0.3, 0.4, 0.1}. As resource performance is the most important factor

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affecting the urban sensing data collection request.

Figure 5 evaluates the total computation urban sensing data collec-tion costs in terms of the consistency of the vehicles on the road. We compare the performance of the proposed algorithm, edge cell predictive trajectory decision mode and cooperative vehicular mode. It can be seen that the edge cell predictive trajectory decision mode scheme reduces greatly the cost when the road seems to have a highly number of vehicle.

Furthermore, a large portion of the off-loaded sensing data collec-tion tasks on the Mobile edge computing SDN controllers can be accomplished within the defined period when the vehicles accessing RSU controller have not been altered. Therefore, there is no need to adopt direct vehicular cloud strategy.

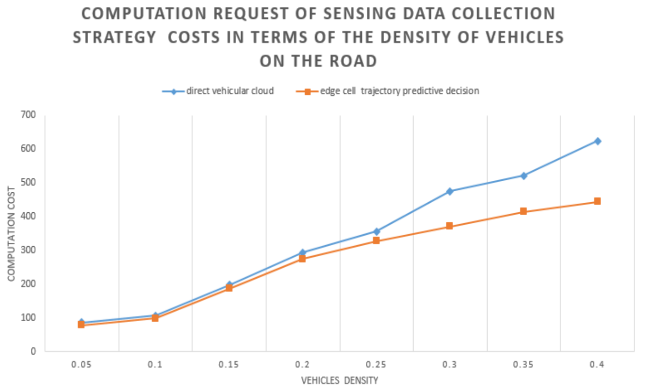

Figure 5. Computation request of sensing data collection strategy costs

V. CONCLUSION

In this article, we proposed a sensing data collection schemes in Software defined mobile edge vehicular networks. Based on the schemes, we discussed the strategy based on the number of RSU controller needs to accomplish the sensing data task completion and the request task cost of direct vehicular cloud or edge cell trajectory prediction modes. The results demonstrated that our scheme greatly reduces the sensing data collection cost.

ACKNOWLEDGMENT

This research was supported by The Leading Human Resource Training Program of Regional Neo industry through the National Research Foundation of Korea(NRF) funded by the Ministry of Science, ICT and future Planning(grant number)(NRF-2016H1D5A1910985) and This work was supported by the BB21+ Project in 2018.

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