A Shared Parking Model in Vehicular Network Using Fog and Cloud Environment

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***Abstract*—At the present, the traffic is really in a mess when the number of vehicles is increasing rapidly. As a consequence, finding a parking space is remarkably difficult and expensive. Therefore, solving this problem has attracted the attention of both scientists and companies. Our study also focuses on solving parking problem to relieve the traffic congestion, reduce air pollution and enhance driving effectively. However, unlike other studies, we consider parking problem in the view of IoT. From this perspective, Fog Computing and Roadside Cloud are utilized to find a vacant spot. By utilizing this infrastructures, any parking space at many places can be shared. Then, we analyze and apply the matching theory to solve the parking problem. Accordingly, our proposal not only helps drivers finding an ideal available space but also brings the owners of these places profit. Simulation results demonstrate that the proposed approach is a reliable solution for the finding parking slot.**

***Index Terms*—Parking; Fog Computing; Vehicular Cloud; Matching theory**

I. INTRODUCTION

According to the International Parking Institute (IPI), 60 percent of the world will live in cities in 2030, and IHS Automotive, an industry research group, estimates that the number of vehicles on the roads will tally 284 million, up from 253 million today. This rapid increase leads to the high demand for parking space and during busy periods of the day, it is common for drivers to keep circling in order to search for an available spot. This activity creates many problems and frustrations for drivers. It has been shown that around 30% of the traffic in these congested areas is in fact due to cruising vehicles [1]. Moreover, a study [2] has shown that this would account for waste of 8.37 million gallons of gasoline and over 129,000 tons of CO2 emissions. Therefore, an optimal strategy to find a parking spot can remarkably relieve traffic congestion, reduce air pollution and enhance driving comfortably effectively. These above-mentioned benefits are one of many goals VANET. As a result, solving parking problem is considered as a challenge in VANET. Besides, VANET is now in the progress of merging cloud to constitute cloud-based vehicular network. The new excited field has been received particular attention both in industrial and academic levels [3]–[5]. Like an inspiration, it really motivates we to take parking problem to cloud environment. In this paper, we consider parking problem in the view of Internet of things (IoT), as shown in Fig. 1. There are abundant slots in many areas such as restaurants, bank parking lot, apartment, office building parking lots/garages, and so on. Take a glance at the areas, it is easy to see that the places are characterized by land uses with nearly opposite parking demand schedules. For instance, an office building parking lot is used frequently during daytime business hours, while a restaurant has a high demand for parking in the evening. Therefore, it is extremely wasted if the shared parking policy is not used. Thus, it is realized that these resources of Fog Computing and cloud-based vehicular network as Roadside Cloud can be utilized to find an available parking space. In details, we propose a new robust parking space management system. Our system can cover all available parking spaces which is named RFPARK in large area with Roadside Cloud and Fog Computing. Underlying our design, RFPARK owns an enormous parking space. Therefore, RFPARK can give drivers an ideal vacant parking space based on matching theory approach.

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To the best of our knowledge, no existing studies have utilized Fog Computing and Vehicular Cloud to address parking problem. The paper is organized as follows. Section 2 describes relation works. Section 3 illustrates the proposed system. Section 4 defines the problem as the College Admissions Matching. Simulations results are analyzed in Section 5 and conclusion are drawn in Section 6.

II. RELATED WORKS

As we mentioned above, looking for an empty parking spot in rush hour is a big problem in urban areas, and of great interest, from a research perspective. A number of on-going researches effort could be generally classified into two types: sensors based approach and RSUs based approach. In the sensors based approach [1], [6], [7], fixed sensors are embedded in the parking slots to monitor parking spaces. They detect the availability of slots across some area, and the locations of currently vacant parking slots are spread to the mobile devices and the users can find out a parking in the area. One of the biggest shortcomings of this scheme is that the drivers have to shift their focus from the road to the mobile device they are using. It really is not safe for passengers. It would be better if they are well-guided to an ideal open parking slot. Since, VANET have emerged as an optimal technology to improve not only road safety but also better driving experience. Then, approaches based on

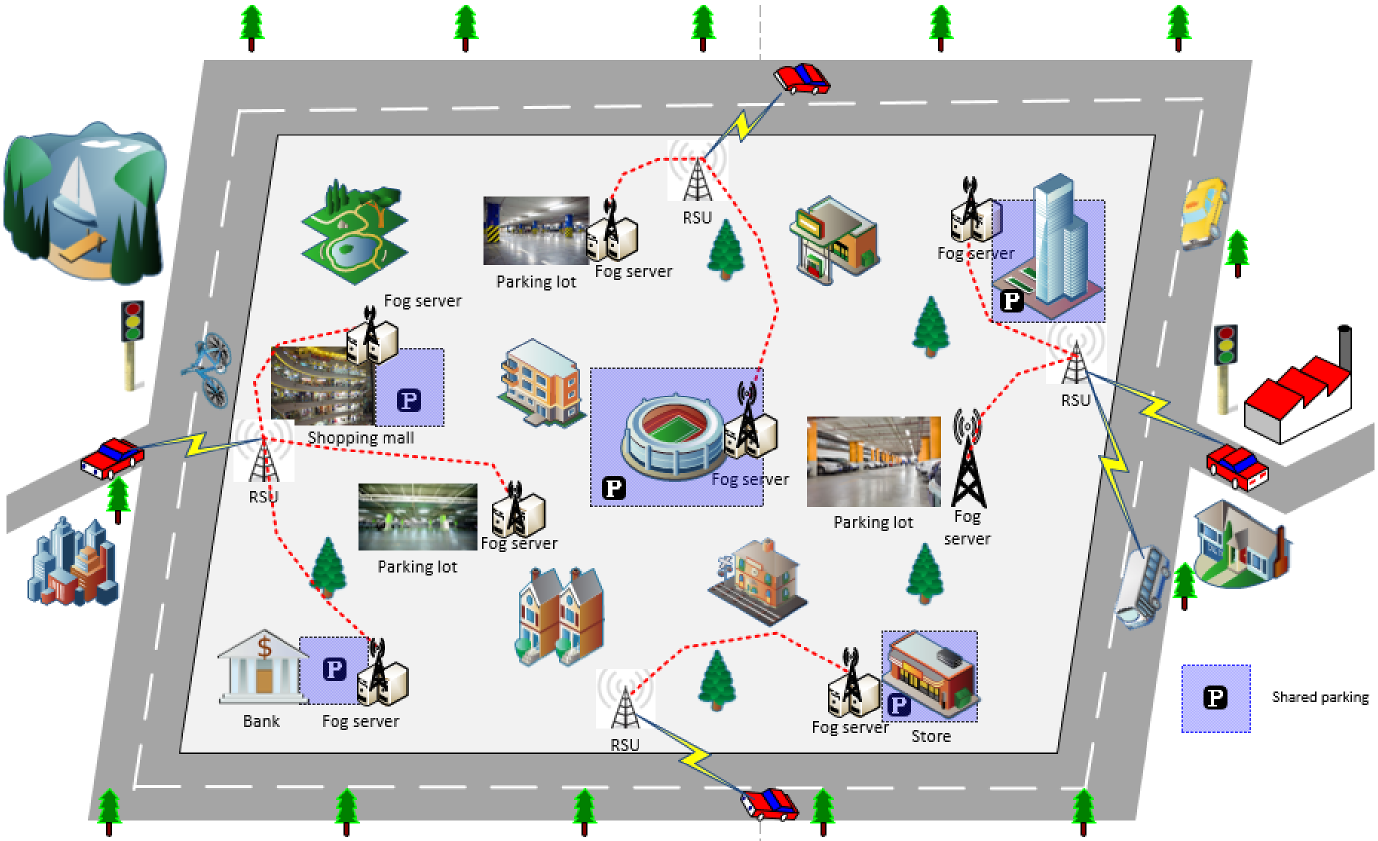

Fig. 1. Overview of parking problem in view of Internet of things (IoT)

RSUs to achieve efficient parking management have also been considered [8]–[10]. In this method, RSUs have been used in order to manage parking lots, and these RSUs can provide available parking space information to the drivers. By using the approach, one parking lot can be managed by multiple RSUs, and thus a synchronization mechanism must be used. This method is very complex and expensive. Both aforementioned approaches only try to solve problems of detecting open slots and guide drivers to arrive at this area. In addition, they just concentrate on available slots in dedicated parking lots. It is a limited view when there are abundant slots in many areas as mentioned earlier. Therefore, it is extremely wasted if shared parking policy is not used. With this in mind, we take Fog Computing and Roadside Cloud concepts into parking problem in order to efficiently enable shared parking policy.

III. System Model

The proposed system model in Fig. 2 is comprised of many parking lots. Status of parking slot, vacant or reserved, will be informed to Fog server that is installed at local areas (banks, shopping halls, restaurant, and so on). Fog servers deliver information of their managed empty spaces to RUSs. At each RSUs, parking slot management/store units which we name **R**oadside Cloud and **F**og computing - based **park**ing slot repository (RFPARK) will communicate with the fog servers in order to direct drivers to an optimal space. In our system model, inside Roadside Cloud, RFPARK will be launched if the request of driver belongs to management of other RSUs.

A. Parking lots

Different from other researches, in our model, both usual parking lots and private parking lots are considered. Parking lots are monitored by embedded sensors or surveillance cameras. Generally, embedded sensors have been deployed at large parking lots such as at shopping halls, at airports, parking lots1, and so on. Meanwhile, to save costs, private parking lots at restaurants, stores, bookstores, etc. can be equipped surveillance cameras. In any manner, vacant spaces can be detected. With this model, an automobilist can park others areas near his expected destination if there is no open slots or the price is cheaper based on his expectation. Besides, owner of private parking lots also earn money from sharing slots. It is visible that economic benefits are brought to both drivers and parking holder.

B. Fog level

The term Fog Computing was first proposed by Cisco in 2012 in [11], [12]. Fog Computing is an extension of the cloud-based Internet by introducing an intermediate layer between mobile devices and cloud, aiming at the smooth, low-latency service delivery from the cloud to mobile . The intermediate Fog layer is composed of geo-distributed Fog servers which are deployed at the edge of networks, e.g.,

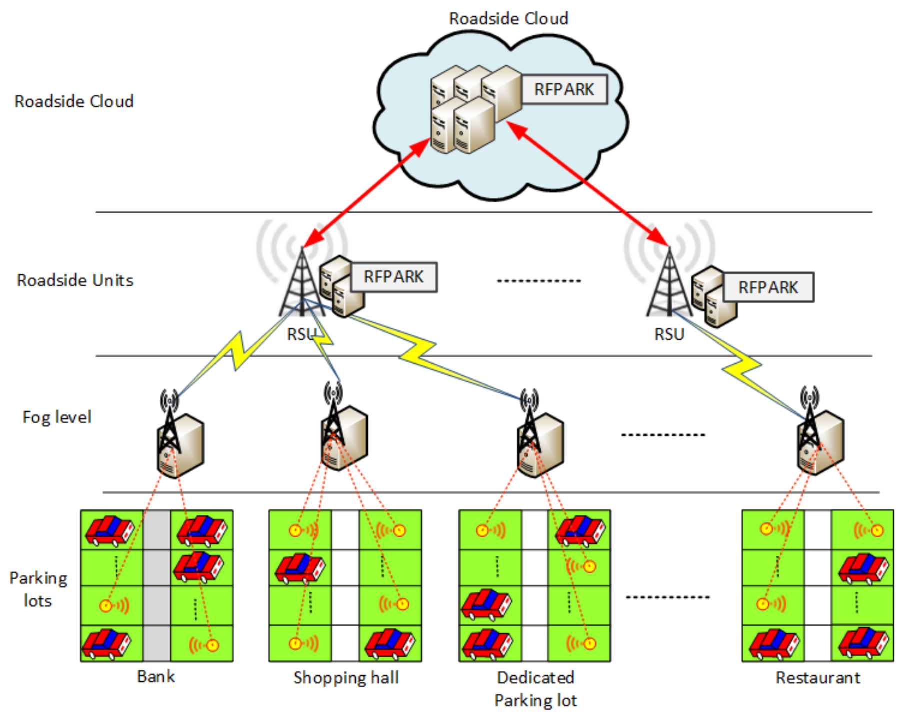

Fig. 2. A shared parking model in Fog and Roadside Cloud environment

banks, bus terminals, shopping halls, etc. Each Fog server is a highly virtualized computing system, similar to a lightweight cloud server, and is equipped with the on-board large volume data storage, computers and wireless communication facility [13]. In our model, the role of Fog servers is to bridge the sensor in parking lots and Roadside Cloud. On the one hand, Fog servers directly communicate with the sensor through single-hop wireless connection such as Bluetooth, WiFi, and Zigbee. By this way, status of parking slots, available or unavailable, is gathered to Fog server. On the other hand, the Fog servers can be connected to the Roadside Cloud in order to transfer data of open slots.

C. Roadside Units

Vehicle will be connected to RSU in its coverage when it owner wants to park. At each RSU, parking slot management/store units - RFPARK is installed. It can reach out to the fog servers that were mentioned earlier, then RFPARK aggregates all vacant slots. As a result, the number of available slots now is extremely huge. Hence, the main goal is with a large figure of open slots in RFPARK what is an ideal slot, the car should park. To address this problem, matching method is used at RFPARK. In detail, parking lot is estimated when the vehicles send its destination. Evidently, at specific time more vehicle will apply to the same parking lot, but each parking lot has a limit vacant slots named as quota. Thus, accepted car will not exceed quota. Remaining car will be considered in order to connect another shared parking lot. With this in mind, matching vehicle to ideal slot is RFPARKs responsibility.

D. Roadside Clouds

In proposed model, Roadside cloud plays a role as an intermediate layer between RSUs to exchange parking lots information. When a RSU receives a required destination that is not in its area, it will send this request to Roadside cloud. Then, Roadside Cloud firstly finds another Roadside Unit in the area of required destination and the process of finding parking slot is performed at this RSU. Secondly, the result is sent back to it and it will transfer to initial RSU. With this mechanism, not only finding but also reserving is completely served. Now, the driver can make parking request at any time, from anywhere, through Roadside Cloud.

IV. Parking slots association as a matching game

A matching game is defined by two separate sets of players that evaluate one another using well-defined preference relations [14], [15]. We formulate the proposed Parking slots association problem in Fog and cloud environment as a many-to-one matching game in which a set of the vehicles $\mathcal{V}$ will be assigned to a set of parking lots $\mathcal{L}$, where each vehicle will be assigned to at most one parking lot. We assume that an arbitrary parking lots l can serve a maximum number of vehicles (quota) q at particular time. The value of q in our model means the max number of available slots of parking lot l. The concept of preferences is used to model the common and conflicting interest. For each vehicle, they prefer to a parking lot which gives they a benefit and comfortable journey as nearing their destination and their current position, and having suitable price. Otherwise, the parking lot only concerns with its revenue. Therefore, it prefers to vehicles which have long duration parking time, and will sell slots with the highest price first. Without loss of generality, we assume that when each vehicle sends parking request, estimated duration parking time is attached. Also, vehicles and parking lot will trust each other. Pertaining to the details of the proposal, basic definitions and notations are defined as follows:

- There are two set of players: a set of *n* vehicles $\mathcal{V}$=$\{v_1, v_2, ..., v_n\}$ and a set of *m* parking lots $\mathcal{PL}s$ $\mathcal{L}$ = $\{l_1, l_2, ..., l_m\}$, where q_i is the quota of the *i*th $\mathcal{PL}$ l_i, and s_{kl_i} is the slot *k*th at the parking lot l_i.
- *d*: $\mathcal{L}$ x $\mathcal{V}\rightarrow$ $\mathcal{R}$ is a distance function from a v_i to l_i or from l_i to vehicles's destination.
- *cost*: amount of money drivers have to pay when they are going to park *v* at l_i.

$$cost(v_i, s_{kl_i}) = \alpha + d \cdot \beta + d \cdot \gamma \qquad (1)$$

  where α denotes the parking fee; d is β is the *driving cost* from a current position to l_i; and γ is the *walking cost* from parking position to destination.
- *price*: amount of profit a $\mathcal{PL}$ l_i gets from a v_i when it parks at l_i. To make our model practically, parking slots in each l_i will have different prices. Therefore, the *price* is determined at a specific s_{kl_i}.

$$price(v_i, s_{kl_i}) = \alpha \cdot t \qquad (2)$$

  where t is the estimated duration parking time of v_i.

Definition 1 A matching is defined as a function from the set $\mathcal{V}\cup\mathcal{L}$ into the set of $\mathcal{V}\cup\mathcal{L}$ such that:

1) $|\mu(v)| = 1$ for each vehicle and $\mu(v) \in \mathcal{L} \cup \emptyset$.
2) $|\mu(l)| \leq q_i$ for $\mathcal{L}$ and $|\mu(l)| \in \mathcal{V} \cup \emptyset$.
3) $v \in |\mu(l)|$ if only if $|\mu(v)| = l$.

Hence, the tuple ($\mathcal{L}$, $\mathcal{V}$, $>_\mathcal{L}$, $>_\mathcal{V}$, $\mathcal{Q}$) determines the parking slots association matching problem with $>_\mathcal{L} = \{>_l\}_{l\in\mathcal{L}}$ being the preference set of the $\mathcal{PL}s$, $>_\mathcal{V}=$ $\{>_v\}_{v\in\mathcal{V}}$ being the preference set of the vehicles, and $\mathcal{Q} = \{q_l|\forall l \in \mathcal{L}\}$.

Vehicles Preferences. From vehicles' side, each v_i seeks to minimize the paid price. Therefore, the *cost* function is computed following Equation (1) in order to rank $\mathcal{PL}s$.

Preferences of the PLs. The proposed matching game can be fully represented once the preference of each $\mathcal{PL}$ over vehicles is defined. Also, there are more vehicles which want to park at a l_i at the same time. Hence,the *price* function that was defined as in Equation (2) as used to determine the rank of vehicles.

Definition 2 A matching μ is stable, if only if no pair of $\{(v,l)|v \in \mathcal{V}, l \in \mathcal{L}\}$ blocks the matching. That is, $\nexists(v,l)$ s.t $v >_l \mu(l), l >_v \mu(v)$.

As mentioned earlier, parking slots association is formulated as many-to-one matching problem. Therefore, the problems now is that is it it possible to find a stable of parking slots association? Parking slots association is identified as college admission problem in which colleges can be viewed as parking lots and students can be viewed as vehicles. The college admission is evidently analyzed in [14], [15] by D. Gale et al.. They proved that it always exists a stable matching of college admission. Hence, a stable set of assignment of parking slots association is completely found.

Algorithm 1 Parking slots association algorithm

Inputs: $\mathcal{L}$, $\mathcal{V}$, $\mathcal{Q}$.
Initialize
  Calculate the preference lists of parking lots and vehicles using Equation (1) and Equation (2).
  Acceptance matrix $\mathcal{A} = \{(v, s_{kl_i})|(v, s_{kl_i})$ prefer to each other$\}$.
Updated quota matrix $\mathcal{Q}$.
Initialize temporary rejected matrix $\mathcal{R}$
While $\mathcal{R}$ is nonempty
step 1: vehicle $v \in \mathcal{V}$ sends its preference vector p_v to the next $\mathcal{PL}$ that is going to apply.
step 2: $\mathcal{PL}$ $l \in \mathcal{L}$ updates its applicant list. $\mathcal{PL}$ l ranks the applicants by their revenue and selects first $\mathcal{Q}(l)$ vehicles and rejects the rest.
step 3: Acceptance matrix $\mathcal{A}$ and the rejection matrix $\mathcal{R}$ get updated. For $\forall v \in \mathcal{R}$.
Outputs: a matching μ.

The result of this algorithm, μ, is a stable matching.

Let us take a look at an example to understand the parking slots association algorithm. Fig. 3 depicts a scenarios of parking problem in Fog and Roadside environment.

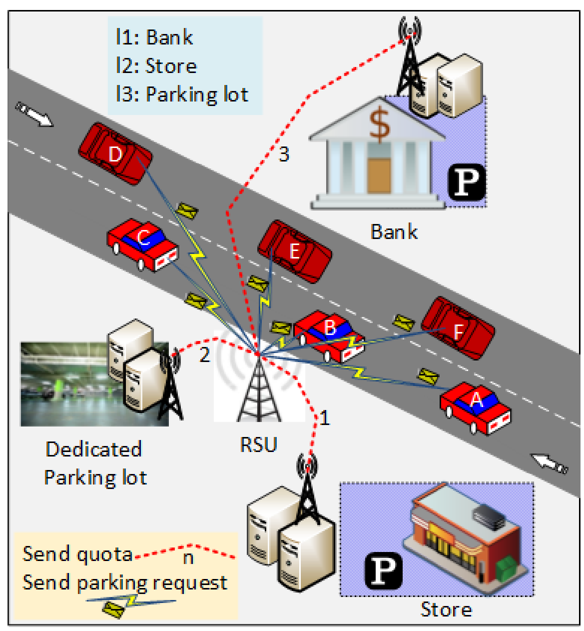

Fig. 3. A scenario of parking problem in Fog and Roadside environment

In this example, there are six vehicles, and three parking lots, one dedicated parking lot and two shared parking lots. Table. I shows the preference of 6 vehicles. Status of 3 parking lots are described in Table. II. From this information, the preference of 3 parking lots is determined as in Table. III. By running the Parking slots association algorithm, the result is shown in Table. IV

TABLE I
PREFERENCE LISTS FOR VEHICLES

A	l2
B	l3
C	l3
D	l3
E	l2
F	l1

TABLE II
THE QUOTA AND THE PRICE ($) OF EACH SLOT FOR PARKING LOTS

quota		1st price	2nd price	3rd price
3	l1	8.2	7.9	7.3
1	l2	10.4	⊠	⊠
2	l3	9.6	8.2	⊠

TABLE III
PREFERENCE LISTS FOR PARKING LOTS

l1	F	A	B	C	D	E
l2	D	A	B	C	E	F
l3	A	B	C	D	E	F

TABLE IV
THE STABLE MATCHING OF PARKING SLOTS ASSOCIATION

l1	E	C	F
l2	D	⊠	⊠
l3	A	B	⊠

V. SIMULATION RESULTS

For simulations, we implement our model and evaluate how efficiently the parking slots association is working. From now, the **p**arking **s**lots **a**ssociation is called PSA matching for short. The simulation is written in python[1]. Simulation's parameters are given in Table. V. Pertaining to the range of values of driving cost, walking cost, and parking fee, these values are choose after we make a survey based on some resources on the internet [2] [3] [4].

TABLE V
SIMULATION PARAMETERS

No.	Parameter	value
1	range	7km x 7km
2	max of vehicles	1000
3	No. of Parking lots	4/RSU
4	quota	$\{250, 450, 150, 300\}$
5	parking fee	1.9-2.9$/1h
6	walking cost	10 cents/km
7	driving cost	31 cents/km
8	duration parking time	10 minutes- 3 hours

In Fig. 4 we show the average cost calculated following Equation (1) from the PSA matching and we compare it to both vehicle optimal stable matching and parking lot optimal stable matching, as the number of vehicles varies.

[1]https://www.python.org
[2]http://transnet.usc.edu/
[3]http://www.utexas.edu/
[4]http://www.wikihow.com

Fig. 4 shows that, as the number of vehicles increases, the average cost of all three schemes also grows up due to the quota limitations of each $\mathcal{PL}$. Indeed, the number of favorable slots decreases as the total number of vehicles rises. We can clearly see that PSA achieves a different tradeoff point between the benefits of two parties. In terms of average cost, the parking lot-optimal stable matching produced by deferred acceptance algorithm outperforms the PSA stable matching by over 13 - 14%. This is because the parking lot-optimal stable matching provides the best performance for $\mathcal{PL}s$ among all stable matching of the problem instance, i.e. the highest parking fee. On the other hand, the performance of vehicles is improved in the PSA stable matching. As seen in Fig. 3, the average cost is around 10,5% better than that of the vehicle-optimal stable matching. That is due to the fact that the priorities defined in the PSA provides a fairer parking slot between vehicles. PSA gives fair tradeoff between the benefits of the parking lot and vehicle. Hence, this result is satisfyingly accepted for the parking operator.

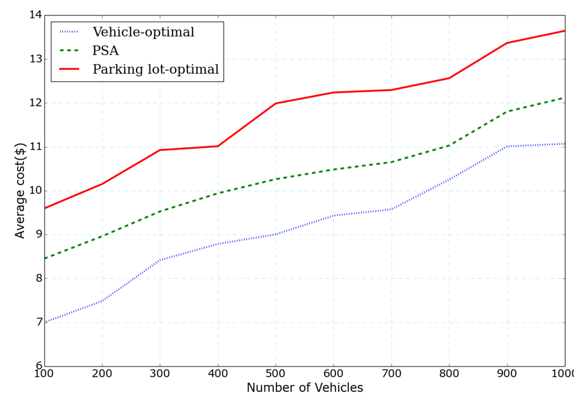

Fig. 4. Average cost per vehicle for PSA, vehicle-optimal, and parking lot-optimal algorithms.

We also compare the PSA with the **Gree**d**y** **a**lgorithm (or GDA for short) for the same problem instance.

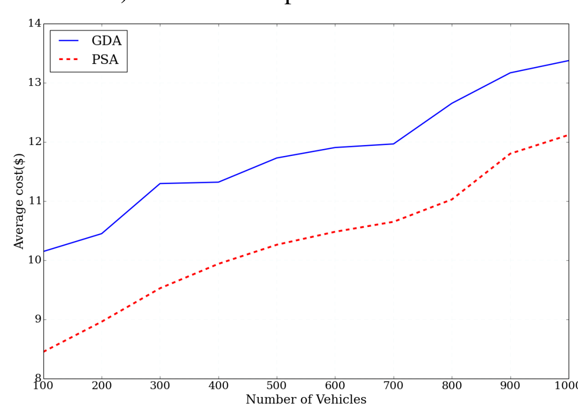

Fig. 5. Comparison between PSA and GDA

Fig. 5 illustrates that PSA has significantly more vehicles achieving cheaper prices, when compared to GDA. It is possible to observe from Fig. 5 that the PSA has a stable gain compared to GDA reaching about 20% of improvement.

VI. Conclusions

Finding parking slot is traditionally sought at dedicated parking lots. However, various areas are characterized by land uses with nearly opposite parking demand schedules such as bank parking, restaurants, shopping halls, ect,. With this in mind, we take Fog Computing and Roadside Cloud concepts into parking problem to construct the shared parking model. With this novel approach, in the next step the problem is analyzed as a many-to-one matching game between vehicles and parking lots. Finally, we propose the parking slots association algorithm for the finding ideal slot. We will consider the influence of others parameter as specific parking time and traffic density to seek an optimal slot in the future work.

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