Optimizing Smart Parking System by Using Fog Computing

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Abstract. Finding the vacant space for parking a vehicle during peak hours is becoming a difficult task at ones end. Parking process whether in shopping malls, restaurants, or offices etc. is a long process and also leads to waste of gasoline. Smart car parking helps in finding the parking slot through Vehicular Ad Hoc Networks (VANET's). For vehicle communication, some devices such as roadside units and on-board units are present that provides parking slot information. In the proposed work, we have introduced an online reservation facility for parking slot. People can reserve their parking space in advance before reaching to their venues in advance. This will help in reducing the waiting time for the parking allocation to the particular vehicle. This will also help to enhance the parking capabilities and will increase the efficiency when compared to other parking strategies. Our proposed approach can minimize the cost of parking on per person basis, exhaust of vehicle, and indirectly it will impact on save of wastage of gasoline and will keep the environment green.

Keywords: VANET · Fog computing · Cost · Vehicles

1 Introduction

Recently with the growth of technology in every possible dimensions of human life, the quality of life has been improved a lot and one can not deny the contribution of various smart applications in this improvement. Several studies have already been performed on these smart applications designed for vehicle parking allocation and management. Finding the best location for vehicle parking in the parking area is one of the time consuming process and also becoming one of the major problem in almost every countries. There are two major problems faced by most of the vehicle owner (1) wastage of time (2) wastage of gasoline [1]. One has to keep on waiting or roaming near parking area unless and until they find any space for parking their vehicle. This scenario leads to vehicles keep on waiting outside the parking space for getting their turn but they have no way to get the information that when their turn will come for parking their vehicle or when an already parked vehicle will leave the parking premises. This results

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into traffic jams outside of most of the parking area. So to overcome from this worst scenario, there is a requirement of an effective and efficient vehicle parking system.

In the proposed smart vehicle parking system and ad-hoc networks and road-side units have been used. Communication devices such as on-board units have also been used for collecting the information regarding availability of parking space and the same has been shared with other vehicles. Number of sensor based devices have been used to implement this smart parking system. Still there are few challenges for VANET based parking system like collection of information and sharing it with other vehicles by using ad hoc network may not support timely updation of information, which can be a critical issue. Thus for real time smart parking systems, VANET based parking system provide a perfect solution for many types of parking related problems [2]. In order to overcome from the above-mentioned problems of allocation of parking space using VANET, fog computing archetype has been introduced in this paper for designing smart parking system.

Fog computing model provides all the resources at the edge of the network. Various fog nodes will be available near each parking premises that will provide the information related to availability of parking area to the vehicles and help them to take parking decision. Also in addition to that, an online facility has also been provided for the reservation of the parking space in advance. Users can reserve their parking before reaching to any parking premises. User has to register himself first if he is using online reservation for parking. Once he is registered for that online facility, then he can simply login to reserve his parking area before reaching to that place. User can also cancel the reserved parking area and in that case that parking area will be allocated to another vehicle from the waith list. Parking cost will be lesser for the online reservation parking as waiting time is lesser. The information regarding online reservation parking gets updated using fog nodes and also the availability of parking space is checked by considering both the information about online and on spot parking reservation. All the information regarding parking gets up-to-date using fog nodes. Parking requests are processed for both online and on spot parking area by using fog nodes. Requests that are in waiting list gets uploaded to the cloud for their further later processing as per the availability of the parking space. Allocation of parking area is provided by applying fog computing to VANET based real time parking systems.

2 Related Work

For finding parking area, smart parking makes use of information and communication technologies, fog computing, and cloud computing. Previously, a number of studies have been done to resolve the issue of allocation of parking space by number of researchers [3–8]. However, smart transportation is getting more attention nowadays. In [9–14], for smart parking, fog computing was applied that

support various computations and also reduces the response time. Fog computing provides various resources at the edge of the network that is closer to the sensors and IoT devices.

2.1 Smart Parking Models

In [15], Zhu et al. have introduced five sensor cloud pricing models. Each model of sensor cloud pricing examines the following aspects: contract span of each sensor cloud user, running schedule of sensor cloud, resources utilization of sensor cloud by each sensor cloud user, sensitive data volume and the path that sensor cloud follows to communicate sensitive data to sensor cloud user through wireless sensor network. In [9], Balzano and Vitale have presented a model in which vehicle to vehicle, distance geometry problem and wireless positioning have been considered. Proposed model was aligned for the indoor navigation in the parking areas. This model also provides facility of anti-theft and anti-collision protection and helps in finding the area and location for the parking of a vehicle. In [16], Hou et al. have discussed a novel system model for computation and communication of available resources. They have introduced the vehicular fog computing model for the direct communication between vehicles. In [17], Huang and Xu have used adaptive content reservation scheme model for the reservation of data in vehicular cloud-fog network. The proposed scheme is used for the quality of service in real time streaming. Tokens are used for preallocating the content in the real time streaming in the proposed model. In [18], Kim et al. have introduced a shared parking model based on roadside cloud and fog computing parking slot repository (RFPARK) in which vehicles will directly communicate with the fog servers. User can make request for parking anytime that will be processed using fog server. In [19], Mukherjee et al. have introduced a framework model for reducing the traffic overhead in industrial applications. This framework helps in preventing the uploading of irrelevant data to the cloud data centres. In [20], Zhang et al. have proposed hierarchical resource management model for optimizing the performance of cooperative fog-computing based intelligent vehicular network. Distributed computation and storage is possible using this model. Inter-fog and quality of service resource management has also been included in this proposed model. In [21], Park and Yoo have used fog computing, Software Defined Networks (SDN), and Fifth-Generation (5G) networks based model for managing the network state information, connection recovery and server failure recovery process. In [22], Rajabioun and Ioannou have used multivariate spatiotemporal models for predicting the available space in the parking lot. The proposed model is also used for recommending the location for the parking of the vehicles. The availability for the parking location is checked in both context i.e. on-street and off-street. In [23], Mei and Tian have introduced a parking choice behavior model for analyzing the parking choices of the users. Parking guidance model is also used for the prediction of parking guidance and information.

2.2 Smart Parking Algorithms

In [10], Wang et al. have discussed the distance geometry problem (DGP) algorithm for determining the graph that will represent best network for the parking. This algorithm also helps in finding the location of the vehicles in the parking area. Availability of parking area will be easily shown to the user by using DGP algorithm. In [18], Kim et al. have used the parking slots association (PSA) algorithm for finding available area for parking. This algorithm helps in allocating the parking area to the vehicles in the fair manner. Also fair tradeoff is also discussed between vehicles and parking areas by the discussed PSA algorithm. In [20], Zhang et al. have used the inter-fog quality of service aware resource management algorithm for enhancing the load balancing and stability of fog network. Resource management behavior is managed by the coordinator through balancing data flow of local fog servers. In [23], Mei and Tian have discussed the standard genetic algorithm for finding any illegal parking in the parking space. Proposed algorithm is responsible for finding the available space and location of the parking space in the parking area for the vehicles. In [24], Zoeter et al. have used an algorithm for calculating the parking charges of the parked vehicles in the parking area. Parking rates will be high if there is any congestion otherwise reduced rates will be applied accordingly.

3 Methodology

To overcome from the various issues related to allocation of parking area as discussed in the previous section, we have proposed a fog computing based system model for smart vehicle parking as shown in Fig. 1. Fog servers have been used whether the space is vacant or filled will be informed to each fog node and similar information is updated throughout all the fog servers. The information for available space is delivered to all the roadside units (RSUs) by fog servers which is independent of geographical location of parking area. proposed system model consist of following layers:

- ***Parking area*** - represents both public and private area for vehicle parking. Here, parking of vehicles is under the surveillance of CCTV cameras and sensors and are also embedded for the monitoring purpose. With the help of sensors available spaces for the parking can be detected. Benefits of smart parking can be for both owner of the vehicle and the parking in-charge.
- ***Fog Nodes*** - In the proposed system model, we have used fog computing for the smart vehicle parking system. Fog computing is an extension of cloud computing that can easily process the user requests as it provides resources at the edge of the network. In the proposed model, fog nodes consist of sensors and fog servers. Information regarding available and occupied spaces in the parking area is further updated with all the fog servers.
- ***Roadside units*** - It help the vehicles to communicate with each other. Roadside units find the parking related information on availability basis and send

it to the requesting vehicles. Vehicle owner can also make requests accordingly. Request is further processed by the fog nodes and information regarding request gets stored in the cloud for future purpose.

– ***Cloud*** - All the information related to the vacant spaces and occupied spaces in parking area gets collected on timely basis and sent to cloud via fog-nodes, for information storage. Requests of all vehicles gets processed according to the updated information present in the cloud.

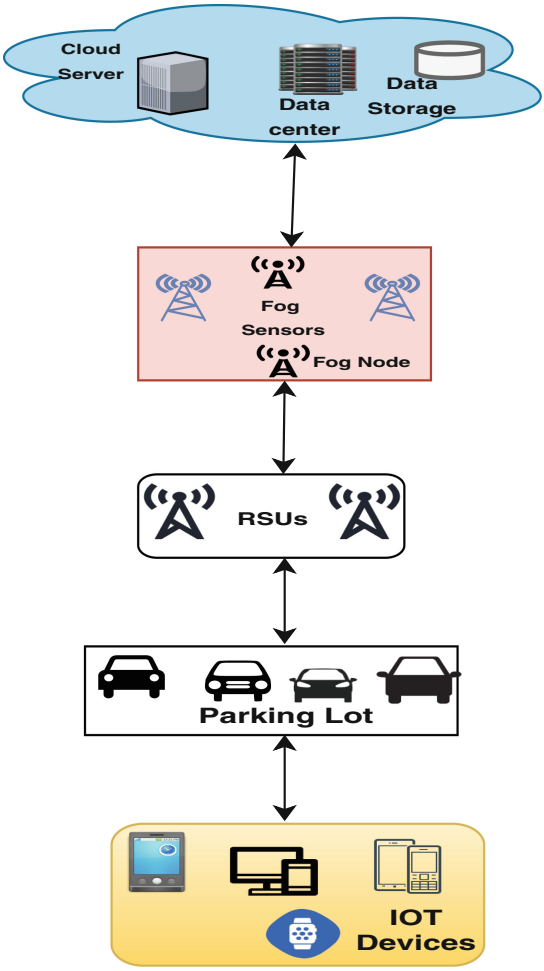

Fig. 1. Proposed smart vehicle parking model using fog environment.

3.1 On-Line Vehicle Reservation Parking

On-line reservation for vehicle parking facility has been provided in the proposed model. User can register for reserving the vehicle parking on-line. Once vehicle owner completes the one time on-line registration process, they can reserve the parking area before reaching to that place. One can also cancel the reservation for parking if there is any previous reservation done for parking area. In this case, user who is in waiting list gets allocated the space in the parking area. The information regarding on-line reservation also gets updated to the cloud so that other vehicle owner who have requested for the parking area can be allocated the space in the reserved parking area. This parking information has to be synced with the parking model of fog environment for smart parking purpose. The on-line process for the parking reservation of the vehicles gets tracked using fog nodes. Fog nodes frequently updates the availability of parking space on the clouds. Vehicle owner whose parking space is reserved before hand, must reach timely to the parking area otherwise that parking area gets allocated to other from the wait list. On-line vehicle reservation parking system is more beneficial as compared to on-spot parking system which is still in use in most of the countries. In on-line reservation parking, one can reserve the parking area for any particular day. Once the parking space is reserved and confirmed, then one need not to wait in the long waiting queues for parking a vehicle and will obtain the location for parking his vehicle (Fig. 2).

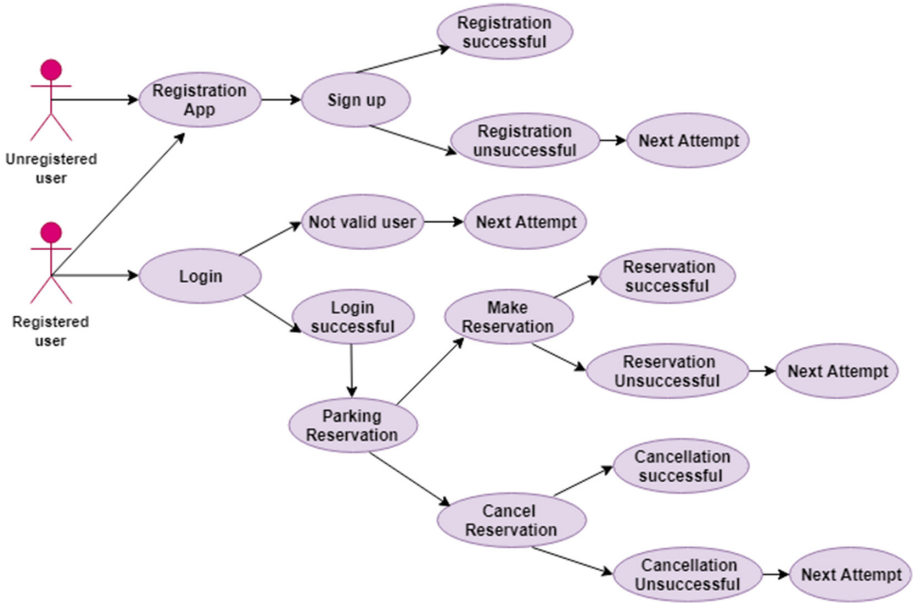

Fig. 2. A use case diagram for on-line vehicle reservation parking.

3.2 Proposed System Design

In this section, we have considered reservation parameters for parking so that the waiting time of vehicles could be minimized. In this paper, we have mentioned how the parking requests are further processed. Fog nodes have been used for storing and managing the below parameters and status of parking lot. For the proposed work we have considered the following parameters:

- ***Parking ID (PID)*:** Smart parking premises in the cities are assigned with unique identification that differentiates one parking area from other.
- ***Parking area status (PS)*:** Status of the parking area gets checked whether the requested space is occupied or not. If space is occupied during the requested period then set $PS = 1$ otherwise set $PS = 0$.
- ***Vehicle ID (VID)*:** Each vehicle is represented by unique identification number via its number plate. This identification can also be used to find which vehicle is parked at particular parking slot. On board units present in the vehicles can also be used as unique identification for the vehicles.
- ***Time Stamp (TS)*:** At parking place when vehicle owner starts to park their vehicles, the time taken is recorded in this time stamp field. If PS is zero, this field will be kept empty.
- ***Time duration (TD)*:** When fog-nodes interact with vehicles, they can find out the parking slot status. So time duration can also be used to find the approximate parking time.
- ***Special quota (SPL)*:** Some parking space in the parking area is reserved for special purpose. So that parking comes under special quota for granted people.

Vehicles that want to send parking request first has to initialize the connection with roadside units and fog-nodes. Once the connection has been established, request for parking could be sent by vehicle to fog-nodes. Fog-nodes further send that request to cloud for checking the status of parking area for the mentioned period. If the space is available then this information is delivered to the requesting entity through the fog-nodes. If the space is fully occupied for the mentioned period then the request for parking will be processed later and updated information is provided to the requested vehicle once the wait list gets cleared (Fig. 3).

- ***Parking allocation cost*:** Here, many factors affect the decision making for assigning parking space to the vehicles like parking priorities, parking fees, wait time and number of requests for parking space. Parking requests are processed according to the availability of the parking area. The total cost for allocation of parking area can be calculated as follows:

$$Totalcost = cost_{waiting} + cost_{timeduration}$$

Sensors like surveillance cameras will monitor the vehicles and fog-nodes will keep the track of vehicles that are waiting at the parking entrance. The parking request will be processed based on the confirmed information sent by the vehicle.

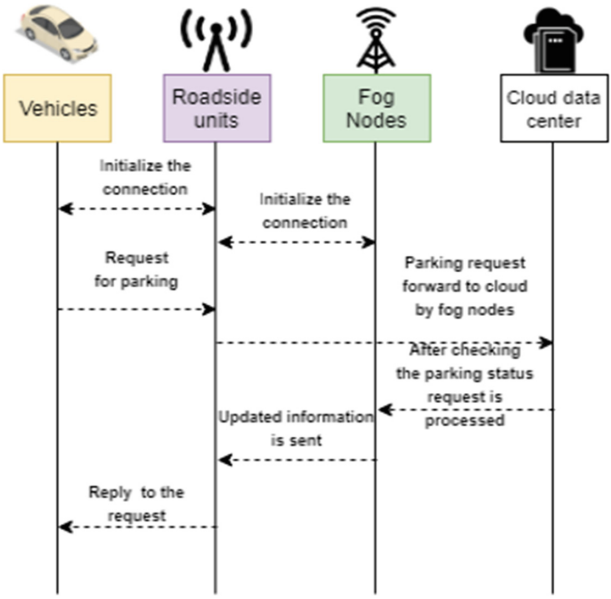

Fig. 3. Vehicles request for parking.

Waiting queue can also be monitored. Estimation time for each vehicle as it arrives can be calculated by fog-node based on the parking request of vehicles. Parking space information is further upgraded after every fixed time interval and is denoted by T_{inv}. The count of number of vehicles that are waiting at the parking entrance is denoted by Num_{Vi}. Total waiting time is expressed as T_{Wi}. We have calculated the minimum number of updates for parking space:

$$M_{min} = mi \left\{ M | \sum_{n=1}^{M} VCSL[j] \geq Num_{vi} \right\} \tag{1}$$

where $VCSL[j]$ = Number of vacant slots for parking

Waiting time can now be expressed as follows:

$$T_{wi} = M_{min} \times T_{inv} + T_{dur}$$

where T_{dur} is the time duration that starts when vehicle begins to park till whole parking procedure is finished. Waiting cost for vehicle i can be expressed as $Cost_{waiting}$ and is calculated as follows:

$$Cost_{waiting} = L \times T_{Wi} \tag{2}$$

where L is the waiting cost per time unit.

3.3 Proposed Algorithm for Parking Area Allocation

In this section, we have used modified greedy algorithm for the allocation of parking area to the vehicles. Fog-nodes keep the track of all the requests made by vehicle owners. Parking status gets checked before allocating the parking space to the vehicles. Here parking request is received by the fog-nodes. After receiving the request for the parking space, availability will be checked for the available parking area. If the space is available for the parking, then the particular request for the parking gets processed and location is assigned to the vehicle accordingly. If the parking space is not available at that particular time, then that request for parking will be uploaded to the cloud data center and processed later-on. After assigning the location to a vehicle, the total cost gets calculated for the vehicle by considering the waiting time and time duration.

Algorithm 1. Modified Greedy Algorithm

Input: Fog Nodes (FN), parking status, parking requests by vehicles PReq.
Output: Decision of parking slot allocation.
Procedure:1. IF Parking request is received by fog node DO
2. Check for available space.
3. IF AVLS[i] $>$ 0 THEN
4. Parking request is processed by assigning LOC[i].
5. ELSE
6. Parking request will be uploaded to cloud data center.
7. FOR k=0:N DO
8. IF vehicle is parked at parking location DO
9. Calculate the total cost (by considering waiting time and time duration)
10. END
end Procedure

4 Experimental Results

The initial experimental setup starts by considering the intake capacity of parking lot for parking. Once parking space capacity is mentioned, proposed system can allocate parking area to the each requesting vehicles. Proposed system also consider the time duration of parking as one of the input. This ensures in calculating the waiting time for the vehicles. A vehicle for which online reservation for the parking is done need not to wait for the allocation of the parking space. Fog-nodes helps to share the parking information among other requesting vehicles. Fog-nodes tries to process the parking requests in the order they are received by the servers. This also keeps the track of online parking requests and processes them according to the vacant space available. Total cost is calculated by considering the waiting time and time duration.

In the experimental results we have used modified greedy algorithm for parking space allocation in which cost calculation is modified by considering the different parameters. Figure 4 represents the average cost for on-spot parking for the various number of parked vehicles. Whereas, Fig. 5. represents the average cost for on-line reservation parking for the various number of parked vehicles. We have evaluated our results by calculating the total cost. The comparison of total cost for on-spot parking and on-line parking reservation is also shown in Fig. 6. Obtained results shows that the total cost of using on-line reservation for parking is less as compared to the total cost for on spot parking by using fog nodes.

From Table 1, it is clear that the average cost for the on-line reservation parking is less as compared to on-spot parking average cost. The number of

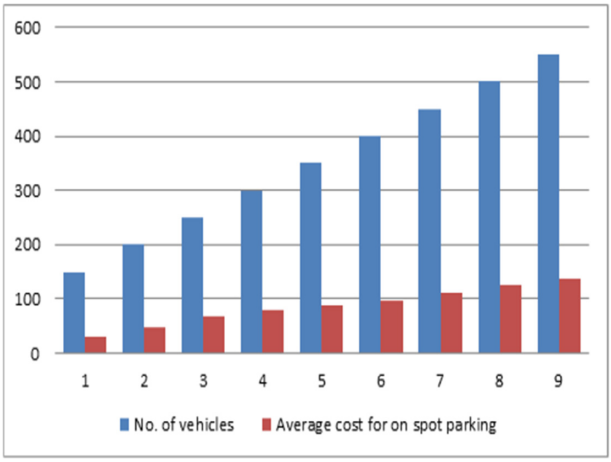

Fig. 4. Number of vehicles versus average cost for on spot parking using fog nodes.

Table 1. Average cost for on spot and online reservation parking

Number of vehicles	Average cost for on spot parking (cost per minute)	Average cost for online reservation parking (cost per minute)
150	30	14
200	48	32
250	67	51
300	79	63
350	87	71
400	98	81
450	110	93
500	125	106
550	138	118

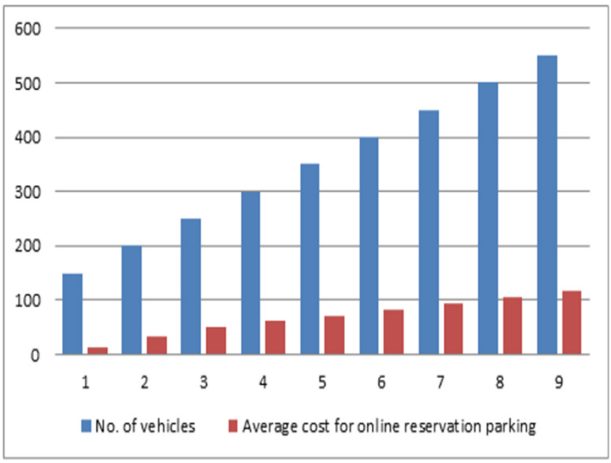

Fig. 5. Number of vehicles versus average cost for online reservation parking using fog nodes.

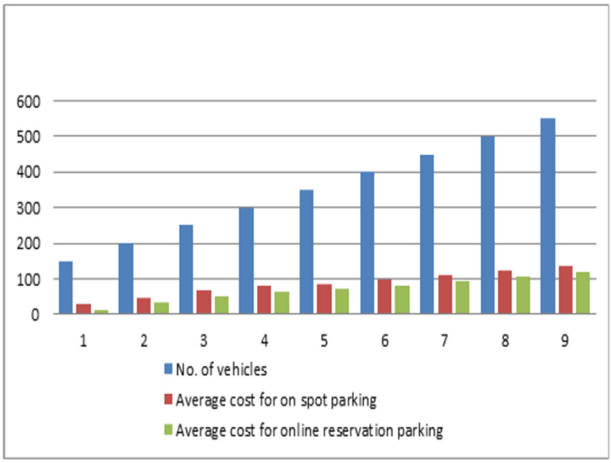

Fig. 6. Comparison between average cost for on spot parking and online reservation parking using fog nodes.

vehicles whose parking request has been processed by the fog-nodes according to the availability of the parking space, proposed algorithm will calculate the total cost for that particular vehicle. In case of on-spot parking, the parking request will be processed in the order as the vehicle arrives in the parking area. In on-line reservation of parking, the parking request of user will be processed on-line and the information regarding availability of the parking space in the parking area gets updated on-line. One need not to wait in the parking queue to know the parking status of the vehicles in case of on-line reservation parking is done

successfully. Therefore, there is difference between total cost of parking a vehicle using on-line reservation as compared to on-spot reservation. Proposed algorithm calculate the cost for different vehicles and the results for both the on-spot and on-line reservation parking is displayed in the Table 1. Also the comparison between average cost for on spot and on-line reservation parking is shown in Fig. 6 which clearly indicates that the average cost for on-line reservation parking is less as compared to the on spot parking.

5 Conclusion

Nowadays, parking problem is becoming an important research issue due to the increase in the number of vehicles. In this work, we have proposed an online reservation facility for parking area that helps to reduce the waiting time and cost of parking on per vehicle basis. We have proposed a modified greedy algorithm to calculate the total cost of the vehicles. The results have shown that the total cost for parking using online reservation is less as compared to on-spot parking by using fog nodes. Online reservation for parking is more efficient and reliable. Obtained results also shows the significant improvement to resolve the parking problems in more efficient manner by allocating the parking space to more number of vehicles. In future work, we will try to use enhanced algorithms for parking strategies.

References

1. Aydin, I., Karakose, M., Karakose, E.: A navigation and reservation based smart parking platform using genetic optimization for smart cities. In: Proceedings of 5th International Istanbul Smart Grid and Cities Congress and Fair (ICSG), pp. 120–124. IEEE (2017)
2. Tang, C., Wei, X., Zhu, C., Chen, W., Rodrigues, J.J.P.C.: Towards smart parking based on fog computing. IEEE Access **6**, 70172–70185 (2018)
3. Lin, T., Rivano, H., Le Mouël, F.: A survey of smart parking solutions. IEEE Trans. Intell. Transp. Syst. **18**(12), 3229–3253 (2017). https://doi.org/10.1109/TITS.2017.2685143
4. Hassoune, K., Dachry, W., Moutaouakkil, F., Medromi, H.: Smart parking systems: a survey. In: Proceedings of 11th International Conference on Intelligent Systems: Theories and Applications (SITA), Mohammedia, pp. 1–6, (2016). https://doi.org/10.1109/SITA.2016.7772297
5. Idris, M.Y.I., Leng, Y.Y., Tamil, E.M., Noor, N.M.: Car park system: a review of smart parking system and its technology. Inf. Technol. J. **8**(2), 101–103 (2009). https://doi.org/10.3923/itj.2009.101.113
6. Polycarpou, E., Lambrinos, L., Protopapadakis, E.: Smart parking solutions for urban areas. In: Proceedings of 14th International Symposium on A World of Wireless, Mobile and Multimedia Networks (WoWMoM), Madrid, pp. 1–6 (2013). https://doi.org/10.1109/WoWMoM.2013.6583499
7. Delot, T., llarri, S., Lecomte, S., Ceneratio, N.: Sharing with caution: managing parking spaces in vehicular networks. Mob. Inf. Syst. **9**(1), 69–98 (2013). https://doi.org/10.3233/MIS-2012-0149

8. Mahmud, S.A., Khan, G.M., Rahman, M., Zafar, H.: A survey of intelligent car parking system. J. Appl. Res. Technol. **11**(5), 714–726 (2013). https://doi.org/10.1016/S1665-6423(13)71580-3
9. Balzano, W., Vitale, F.: DiG-Park: a smart parking availability searching method using V2V/V2I and DGP-class problem. In: Proceedings of 31st International Conference on Advanced Information Networking and Applications Workshops (WAINA), Taipei, pp. 698–703 (2017). https://doi.org/10.1109/WAINA.2017.104
10. Wang, T., et al.: Data collection from WSNs to the cloud based on mobile Fog elements. Future Gener. Comput. Syst. (2017). https://doi.org/10.1016/j.future.2017.07.031
11. Wang, T., et al.: Fog-based storage technology to fight with cyber threat. Future Gener. Comput. Syst. **83**, 208–218 (2018). https://doi.org/10.1016/j.future.2017.12.036
12. Gupta, P.K., Maharaj, B.T., Malekian, R.: A novel and secure IoT based cloud centric architecture to perform predictive analysis of users activities in sustainable health centres. Multimed. Tools Appl. **76**(18), 18489–18512 (2017). https://doi.org/10.1007/s11042-016-4050-6
13. Malekian, R., Kavishe, A.F., Maharaj, B.T., et al.: Smart vehicle navigation system using hidden Markov model and RFID technology. Wirel. Pers. Commun. **90**(4), 1717–1742 (2016). https://doi.org/10.1007/s11277-016-3419-1
14. Gupta, P.K., Tyagi, V., Singh, S.K.: Predictive Computing and Information Security. Springer, Singapore (2017). https://doi.org/10.1007/978-981-10-5107-4
15. Zhu, C., Li, X., Leung, V.C.M., Yang, L.T., Ngai, E.C., Shu, L.: Towards pricing for sensor-cloud. IEEE Trans. Cloud Comput. (2017). https://doi.org/10.1109/TCC.2017.264952C
16. Hou, X., Li, Y., Chen, M., Wu, D., Jin, D., Chen, S.: Vehicular fog computing: a viewpoint of vehicles as the infrastructures. IEEE Trans. Veh. Technol. **65**(6), 3860–3873 (2016). https://doi.org/10.1109/TVT.2016.2532863
17. Huang, C., Xu, K.: Reliable realtime streaming in vehicular cloud-fog computing networks. In: International Conference on Communications in China (ICCC), Chengdu, pp. 1–6 (2016). https://doi.org/10.1109/ICCChina.2016.7636838
18. Kim, O.T.T., Tri, N.D., Nguyen, V.D., Tran, N.H., Hong, C.S.: A shared parking model in vehicular network using fog and cloud environment. In: Proceedings of 17th Asia-Pacific Network Operations and Management Symposium (APNOMS), pp. 321–326. IEEE, Busan (2015). https://doi.org/10.1109/APNOMS.2015.7275447
19. Mukherjee, M., Shu, L., Wang, D., Li, K., Chen, Y.: A fog computing-based framework to reduce traffic overhead in large-scale industrial applications. In: Proceedings of Conference on Computer Communications Workshops (INFOCOM WKSHPS), Atlanta, pp. 1008–1009. IEEE (2017). https://doi.org/10.1109/INFCOMW.2017.8116534
20. Zhang, W., Zhang, Z., Chao, H.: Cooperative fog computing for dealing with big data in the internet of vehicles: architecture and hierarchical resource management. IEEE Commun. Mag. **55**(12), 60–67 (2017). https://doi.org/10.1109/MCOM
21. Park, S., Yoo, Y.: Network intelligence based on network state information for connected vehicles utilizing fog computing. Mob. Inf. Syst. 1–9 (2017). https://doi.org/10.1155/2017/7479267
22. Rajabioun, T., Ioannou, P.A.: On-street and off-street parking availability prediction using multivariate spatiotemporal models. IEEE Trans. Intell. Transp. Syst. **16**(5), 2913–2924 (2015)

23. Mei, Z., Tian, Y.: Optimized combination model and algorithm of parking guidance information configuration. EURASIP J. Wirel. Commun. Netw. (1), 101 (2011)
24. Zoeter, O., Dance, C., Clinchant, S., Andreoli, J.: New algorithms for parking demand management and a city-scale deployment. In: Proceedings of International Conference on Knowledge Discovery and Data Mining, pp. 1819–1828. ACM (2014)