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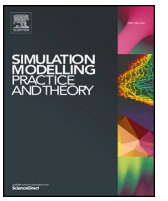

Learning automata and reservation based secure smart parking system: Methodology and simulation analysis

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ABSTRACT

The increase in the number of vehicles on roads has compounded the difficulty in parking them when people go out for movies, shopping, theatre, etc. Thus, this paper proposes smart parking system. The reservation of the parking slots can be made using this proposed smart parking system. Unlike the methods proposed in the existing research, the system proposed in this paper divides the parking area into 3 parts. One for conventional parking, one for vehicles with reservation and the other for the vehicles with and without reservation. Learning automata is used in the proposed system to determine the percentage of the parking area for conventional parking. In general, the proportionate of the slots for reserved parking, conventional parking and common slots need to be assumed. Learning Automata helps in determining this proportionate optimally. The AES-256 encryption algorithm is used to provide security for the details provided by the user during reservation process. Goodput value is maintained for each vehicle which increases or decreases the chances of getting a reservation. The time limit for the reservation of the parking slot is also maintained after which the reservation gets cancelled automatically. Markov Model is used to represent the system. The performance of the proposed algorithm, Learning Automata and Reservation based Secure Smart Parking System (LA-RSSPS) is simulated and evaluated in terms of average waiting time, search time, the probability with which the vehicles do not get parking slot when they do not have reservation and the probability with which the vehicles do not get reservation and is compared with ProNet and iERS. Results have shown that our scheme preforms better than the ProNet and iERS competing schemes. The comparison of analytical and simulations results are also presented.

1. Introduction

The Smart Parking System (SPS) helps in the improvement of traffic management system. SPS helps in minimizing the expenditure spends on the human labor and best usage of the parking area by the vehicle users. At present, the user is identifying the parking slot on roads manually, which wastes his/her valuable time. Sometimes, the user will not be able to find the slot at the required destination area if the traffic of vehicles is more during the respective time and day. These issues can be resolved if the parking slots can

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be defined before the user reaches the destination location. However, generally the parking areas might be far away from the user's current existing location. Different networking technologies like RFID (Radio Frequency IDentification), Wi-Fi, etc., and Internet [1] are used to make vehicle communicates other vehicles [2] or infrastructure [3]. To resolve all the issues mentioned till now, the details related to the availability of parking slots need to be apprised to the users and allow users to reserve the vacant parking slot on beforehand with the help of their handheld devices.

The people who drive in the cities were facing a challenge in identifying a vacant parking place in a parking place nearer to the destination location. The search in the parking area leads to waste of time, increases the fuel consumption, and traffic jam and also soars the level of pollution in the air. This might lead to accidents also in some cases [4]. All these problems lead to the search in efficient parking system. The solution is the development of smart parking system using latest and advanced technology. Using this smart parking system, the parking of vehicles can also be streamlined. The cities where the parking of vehicles is made on road side, this smart parking system will help greatly to park the vehicles without wasting the space. It allows to park the vehicles in a proper order instead of in a scrambled manner. Moreover, it suggests the parking area which reduces the traffic on roads and pollution in the atmosphere. Smart and effective parking systems can be developed using Internet of Things (IoT). It helps in connecting the vehicles to be parked. Wireless sensor networks are integrated to connect the parking areas, which are capable of providing parking slot with the smart management that is based on the cloud. These vehicles which are connected to each other are termed as smart vehicles. These smart vehicles consist of smart machinery which helps them to commune and act together and also with the environment.

The tracking of vehicles is easy, prior knowledge related to the environment condition, analysis based on sensor values, quick regulation and reaction, among others, are some of the advantages of IoT. There will be different limitations for different applications where IoT technology can be used. Smart parking involves data collection and maintenance, establishment of connection and completeness of the process. The sensing module plays a major role in the system. In this module, the data related to parking location, vehicle, parking request will be gathered and maintained. Some of the Microcontrollers of the IoT applications are ARDUINO, NodeMCU, and Rasberry PI, which help in implementing the operations required to be performed. The processors are included to process the values taken from the sensors. The devices in the network can be made to communicate with each other by connecting them using any networking technology like Wi-Fi [5]. Smart parking systems help people on roads to find the idle place to park their vehicles easily. The time taken to identify an idle space to park the vehicle can also be calculated and can be considered as a metric of smart parking system. Besides identifying a parking space, payment and approval for parking area can also be considered in the implementation of smart parking system. Instead of issuing payment bill in the print form, digital form is far better.

The advantages of smart parking system are enhancement of usage of parking lot efficiently, less time to determine the vacant parking slot and hence reducing the pollution in the air. In smart parking systems, the parking slots reserved for physically challenged and general category need to be easily identified, such that the corresponding slots can be allotted for the respective users. Furthermore, the available, occupied and reserved parking slots need to be clearly indicated in the system. The system must be able to identify any kind of violations. The management of smart parking system is an agile system. This smart parking system if modelled using birth-death model can be used to anticipate the profits and hence can predict an emerging promotions to develop the business. All these emerging promotions, updated parking prices and strategies can be made available to the customers using this smart parking system without any additional investment.

It has been determined that the control of the payment for the parking area might lessen the density of the traffic in the research carried out till now [6]. The pay for the parking area depends on the slot obtained. For example, pay can be high for the slots with constraints and less if the user chooses a slot without any constraint. This kind of scenario is implemented in SFPark of San Francisco [7]. Smart parking system can be developed using Internet of things, fog computing, cloud computing techniques, machine learning algorithms, etc.

Main Contributions of the paper:

- The proposed system divides the parking area into 3 parts. One for conventional parking, one for vehicles with reservation and the other for the vehicles with and without reservation.
- Learning automata is used in the proposed system to determine the percentage of the parking area for conventional parking.
- Security is provided using AES-256 encryption algorithm
- Goodput value is maintained for each vehicle which increases or decreases the chances of getting a reservation.
- The time limit for the reservation of the parking slot is also maintained after which the reservation gets cancelled automatically.
- Markov Model is used to represent the system.
- The advantages of the proposed smart and secure parking system is the users information is secured, less waiting time, effective parking system, the total parking area is divided into 3 partitions: slots for the users who have reservation, slots for the users who do not have reservation and the common slots which can be used by both kind of users. This partition system makes the system more efficient and most of the users more satisfiable.

2. Motivation

It can be noticed that the people struggle in getting parking slot in cinema theatres, shopping malls, restaurants etc. Some people use to change the destination location as they weren't able to get the parking slot. Obviously this makes the people disappoint and they will not be completely satisfied as they are not able to go to the restaurant or shopping place where they are actually willing to. Literature survey says that the waiting time to get a parking slot is 20 min on an average. This waiting time wastes the fuel, and invaluable time of the people. Many researchers proposed many smart parking systems. People need to provide some information to

reserve the parking slot and make use of these smart parking systems. Even though there are many useful applications for different purposes, most of the people do not use them with the afraid that the information provided might be misused. This motivated in performing research in this area to propose secure smart parking system so as to make people more convenient, comfortable in parking their vehicles in the destination locations.

The rest of the paper is organised as follows. Section 2 presents the related work that is carried out in smart parking system. Section 3 discusses the proposed method, Learning Automata and Reservation based Secure Smart Parking System (LA–RSSPS). Performance analysis is studied in Section 4, results are discussed in Section 5 and finally, Section 6 concludes the paper.

3. Related work

A smart parking system which uses closed circuit television to determine the location of the vehicle in the parking area, is devised in [8, 9]. The location is determined with the recognition of pixels. The differentiation between presence and absence of the vehicles in the parking area is identified by setting threshold value for pixels and the images are considered to be in grayscale. This system is more consistent, trustworthy, and precise and can be used to obtain information related to vacant space in the parking area.

An assimilated method of image processing procedures referred to as Car Occupancy INformation System (COINS) is proposed in [10] in order to obtain the details whether the vehicle is parked or parking slot is vacant. The COINS is inexpensive as the sensors haven't been used. At the same time, usage of image processing procedures reduces the cost of the system. In [11], the vacant parking slots are identified using the magnetic field of the Earth. The computers which regulate the system are connected to the sensors in this system to obtain the required information.

In [12], an algorithm is proposed for parking method which when implemented is capable of determining when the parking slot is being vacated or occupied by the vehicles. This algorithm is based on radio frequency identification. Also, the driver is made aware about the details of the vacant parking slot which is nearest to the vehicle at that instance. Similar to this, the procedure which is based on radio frequency identification is proposed in [13]. It consists of gate PC regulator and equipment related to implanted gate. It is a flexible system such that controller and equipment might be changed in the system.

The algorithm which enhances the performance of the present smart parking system that is based on the cloud technology is proposed in [14]. Also, IoT is used to build an architecture for the system. Vacant parking slot can be easily identified using this algorithm and it is automated. User parking cost is decided based on the distance and number of vacant slots in the parking area. The parking slot can be allotted to the user when requested based on this cost. The user can be suggested another parking area if there is no vacancy in the requested parking area. The authors claim that the proposed algorithm reduces the wait time of the user and the possibility of getting a parking slot is increased.

The environment considered to implement a smart parking system in [15] is urban. The cost function of the driver is calculated based on how much nearer the user is to the destination and charge for parking slot. This cost function is used to allocate and reserve the most suitable parking slot for the requested user. Using this procedure, at every instant of time when the decision need to be taken, the issue of Mixed Integer Linear Programming (MILP) is resolved. The best suitable allotment of the parking slot which depends on the data at present condition is the elucidation of MILP. This information is made a point during the decision making time at next instance. It is ensured that the clash in the reservation of the resources will be avoided and also ensure that the user with highest cost function is only allotted the parking slot. It is proved that the time taken to identify the parking slot and the charge for the parking slot is reduced. At the same time, it is shown that the proposed algorithm is successful in utilizing the parking space effectively.

Much research is carried out in the smart parking system where multilayer [16], parkagent [17] clamp [18], and parksim [19] are the system proposed in the initial period of the research in this area. In most of the research works, the different parking locations are notified to the user beforehand when the requested parking location is full. E-parking is the advanced system which makes the user aware about the parking details on beforehand when the request is made and also helps in reserving the parking location [20]. Internet helps the user to identify the parking slot. The vehicle is scanned at the entrance of the parking locations to determine whether the vehicle reserved the slot or not and also verifies whether the user paid for the parking slot or not [21].

The combination of two technologies named ultrasonic and radar detection are used to implement smart parking system in the development of smart cities in [22]. The main objective of this proposed approach is to build a parking system, which is self-governing, minimise traffic jams, pollution in the air, waiting time of the users by enabling them to identify the parking slot easily at the time of busy hours also. The involvement of the human will be reduced in this proposed approach of parking system. Wi-Fi module is used to send all the information to the cloud for storage purpose. The unfilled parking slot is identified by the user with the help of the interface. The occupancy and vacancy of the individual parking slot in the parking area is monitored continuously by the system proposed in [22]. A warning alarm will be buzzed by the system when the number of vehicles in the parking location and in travel exceeds the total number of parking locations in the parking area. The same system can used to implement in the parking areas of cinema theatres, shopping malls, universities, etc., and deliver an efficient and cost-effective parking procedure.

A reservation based smart parking system is proposed in [23]. This system enables users to identify the unoccupied parking slot efficiently and reserve the identified slot. The parking areas are embedded with sensors and make the system aware about the vacancy and occupancy of the slots in the parking area and thus the reservation facility is modified. This Cyber Physical System is made accessible by the users with the help of their mobile phones, laptops, or any other mobile devices.

The main objective of the parking system developed in [24] is to make effective utilization of the parking area. The gap amid the vehicles is reduced yet no compromise in the ease of the driver to come out/go into the vehicle. Two variations in the parking systems are discussed in [24]. They are automatic and manual. The parking system, which is manual is more expensive in comparison with

the parking system which is automatic. Internet of Things is the most suitable technology to implement smart parking system and the level 1 of IoT is used in this paper.

The various proposals by different researchers for parking system are discussed and analyzed to identify corresponding advantages and disadvantages in [25]. The authors also developed a smart parking system using IoT. The empty slots in the parking areas can be observed by the users continuously using their cell phones or laptops. At the same time, the proposed system behaves as an access point also.

A smart parking system based on IoT is proposed in [26]. Three different technologies like wireless sensor networks, computer vision procedures and android are used to verify the vacancy in the parking areas, identification of the vehicle arrival at the parking area and interface to the user respectively. The users can identify the vacant slots in the parking area and payment can also be made using the application developed using android.

How the SDN is suitable in VANET is explored in [35]. The methods depending on the clusters, geocasting using road side unit, broadcasting, VANET using cloud, SDN and fog computing are analysed. It is observed that good quality of service will be provided, latency will be reduced and heterogeneity is effectively handled in VANET using SDN. The authors also provided a light on concerns and the problems faced while integrating SDN and VANET. This paper provides the basis which helps in performing the research in this area [35].

Finding a parking slot is becoming difficult as there is huge increase in the number of vehicles which increases the traffic. iERS is a parking system using Internet of Things (IoT) proposed in [36] which helps in locating the nearby parking slot that is vacant. This method also provides navigation to the identified slot.

A Novel Hybrid Heterogeneous LEACH (HHE-LEACH) protocol for Wireless Sensor Networks in [37]. Learning Automata is also used to enhance the performance of the proposed algorithm. The threshold values of distance between the nodes and the base station (BS) determine whether the node will directly communicate with BS or indirectly communicate with BS.

Automated Machine Learning is comprehended, its partitions and corresponding methodologies are investigated in [38]. It is applied in the context of industries and explained. The authors in [39] investigated various methodologies that addressed the provisioning process and scheduling process of public transport and provided concise review to make it suitable for the Indian road constraints. Scheduling procedure for vehicles based on the real-time information collected using GPS and sensors is proposed in [40]. Machine learning is utilised in enhancing the scheduling process. The availability of seat, path choice, fare are used frame the taxonomy of public transport in [41]. Various researchers have used learning automata to enhance the performance in various fields [28-34].

4. Learning automata and reservation based secure smart parking system (LA–RSSPS)

4.1. RSSPS procedure

When the user wants to go to shopping, movie, restaurants, theater, etc. where the parking is required, it is very difficult now-a-days to find a parking spot as number of vehicles on roads are increasing day by day. Thus, it is required to have smart parking system, which makes users comfort in parking their vehicles without any issues. In the proposed algorithm, LA–RSSPS, the users can reserve the parking slot in the parking area nearer to the destination. If the user is not able to identify a vacant slot in the required parking area, LA–RSSPS suggests another nearer parking area. The reservation will be made only for some predefined time. i.e., time for which the reservation is valid. This kind of setting time limit for reservation is introduced as there is a chance that the user might not come to the destination because of the change in the plan due to many reasons. In such a case, the reserved parking slot will be wasted and cannot be allocated for other users. Also, x% of the parking area is not used for reservation and will be used for the users who come directly without reservation. y% of the parking area is used in common for reserved and conventional parking. z% of the parking area is used only for conventional parking. This percentage can be decided using learning automata. One more interesting point is the type of vehicle and subtype of vehicle is considered for parking slot reservation. The type of vehicles might be two-wheeler or four-wheeler. If it is four wheeler, then the subtype of vehicle is considered as the vehicles can be of Innova, i10, desire, Camry, A-Class, C−Class, etc. This information is very helpful to reserve an appropriate slot and effectively use the parking space.

As an initial step, the user needs to select the city where the user is residing. The LA–RSSPS is used to reserve the parking slot only in the city where the user is residing. Later, the user need to select the destination. Hence, the system will be aware that the user is going to movie, shopping, restaurant etc. When the user selects movie, the system prompts for the theatre name, then it prompts whether the user has reserved the tickets or not. If the tickets are reserved, then parking slot will be reserved and time limit need not be set in this case as there is an assurance that the user will definitely come to the destination. When the user selects restaurant as a destination then LA–RSSPS prompts for the name of the restaurant, location of the restaurant, the expected time of arrival and present location of the user. This information is used to set the time limit for the reservation of the parking slot. Before the time limit is getting expired, the warning message is sent to the user. At this point of time, the user can extend the time limit for very few minutes, like 5 min. If the user does not extend the time limit and if the same is expired, the reservation gets cancelled automatically and the message will be sent to the user.

If the user selects the destination as shopping, then the location of the destination need to be specified. If there is private parking area for the corresponding shopping mall/mart, then the reservation can be made in the same. Otherwise, the parking is made on roadside. In such cases, the reservation is not possible, but the density of the vehicles is made known to the user. This is made possible with the help of sensors. Whenever the user reserves the parking slot, it will be recorded whether the user has arrived within the time limit or not. If the user has arrived within the time limit and used the advantage of reserving the parking slot successfully then it

Table 1
Notations used.

Symbol	Description
x%	% of the parking area not used for reservation
y%	% of the parking area used in common for reserved and conventional parking
z%	% of the parking area used only for conventional parking
s_1, s_2, s_3, s_4 and s_5	Input actions to the learning automata
p_1, p_2, p_3, p_4 and p_5	Probabilities associated with input actions, s_1, s_2, s_3, s_4 and s_5
N	Number of Users
T_{W_i}	Waiting time of the user 'i'
T_{Avg}	Average waiting time of the user
$T_{Avg_{Th}}$	Threshold value of the average time of the user
R	Reward constant
P	Penalty constant
P_c	Probability of selected input action to automata
P_d	Probability of action other than selected input action
A	Number of parking areas in the city
S_a	Number of parking slots in particular parking area
S_c	Number of parking slots for conventional parking
S_r	Number of parking slots for reserved parking
λ_R	The arrival rate of vehicles which reserved parking slot
λ_C	The arrival rate of vehicles which do not have reservation
μ_C	The service rate of the vehicles which do not have reservation
μ_R	The service rate of the vehicles which have reservation
S	Total parking slots
S_c	Slots that can be used by the vehicles without any reservation
S_{cr}	Slots that can be used by the vehicles with and without reservation
S_r	Slots that can used by the vehicles, which have reservation.
P(i)	Probability of i vehicles not getting parking slot
$P_{NR}(C)$	The probability with which the vehicles do not get parking slot when they do not have reservation
$P_R(R)$	The probability with which the vehicles do not get reservation

indicates the effective utilization of the smart parking system and the goodput value of the user is increased. Otherwise, it is decreased. This goodput value of the user is not known to the user and is used during the reservation process of the parking slot. When multiple requests are arrived at the server, this goodput value of the user is used to resolve the issue. i.e., the user with high goodput value is allowed to reserve the parking slot. The payment for parking need to be done once the reservation is successful. Finally, an encryption procedure is used to secure the details of the users which are stored in the cloud.

If the user wants to cancel the reservation, it is possible to do it, but the charges for the cancellation vary depending on the remaining reservation time and goodput value of the user is decreased. Fast track system can be introduced at the entrance of the parking such that the vehicles with reservation and paid can be sent immediately without manual verification at the parking area. SpiderOak is used for storage purposes in the cloud in a secure manner using encryption. AES-256 algorithm is used for encryption in SpiderOak.

Table of notations used in this paper is given in Table 1.

4.2. Learning automata process in smart parking system

Learning automata is used to determine the percentage of parking area that can be used for the vehicles without reservation and the percentage of parking area that is common for both conventional and reserved parking. The main objective of smart parking system is to reduce the average waiting time of the users. Periodically, the average waiting time of the users is computed. In this paper, five actions, s_1, s_2, s_3, s_4 and s_5 are considered as inputs to the automaton. The probabilities p_1, p_2, p_3, p_4 and p_5 are associated with each action s_1, s_2, s_3, s_4 and s_5, respectively. All the input actions will have equal probability initially. Therefore, one of the input actions is selected randomly, say s_1. The LA-RSSPS algorithm is executed in the environment and average waiting time of the user is computed.

Let there be 'N' users and T_{W_i} is the waiting time of the user 'i'. Then the average waiting time of the user is given by:

$$T_{Avg} = \frac{\sum_{i=1}^{N} T_{w_i}}{N} \tag{1}$$

If the computed average time of the user, T_{Avg} is greater than threshold value of the average time of the user, $T_{Avg_{Th}}$ then the selected action is rewarded, i.e., probability of the selected action is increased and $T_{Avg_{Th}}$ is updated with T_{Avg}. Otherwise, it is reduced. In next iteration, the action with high probability is selected and the process is repeated. When the probability of any action converges to 1, then the corresponding action is considered to be an optimal action. The value related to the optimal action is considered as the optimal percentage of parking area that can be used for the vehicles without reservation or conventional parking area. RSSPS(c) is a procedure with c, the% of conventional parking. This procedure is explained in section 3.1.

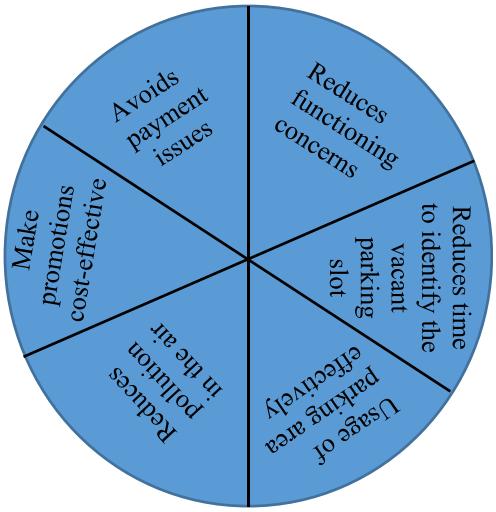

Fig. 1. Advantages of Smart Parking System.

The above algorithm determines the percentage of parking area that can be used for the vehicles without reservation and the same procedure can be used to determine the percentage of parking area that is common for both conventional and reserved parking.

5. Performance analysis

Let:
Number of parking areas in the city = A
Number of parking slots in particular parking area = S_a
Number of parking slots for conventional parking = S_c
Number of parking slots for reserved parking = S_r
The arrival rate of vehicles which reserved parking slot = λ_R
The arrival rate of vehicles which do not have reservation = λ_C
The service rate of the vehicles which do not have reservation = μ_C
The service rate of the vehicles which have reservation = μ_R Fig. 1
The sample layout of the parking area is shown in Fig. 2 and the System model is shown in Fig. 3.
If there are a total of S parking slots, S_c slots can be used by the vehicles without any reservation. This is referred to as

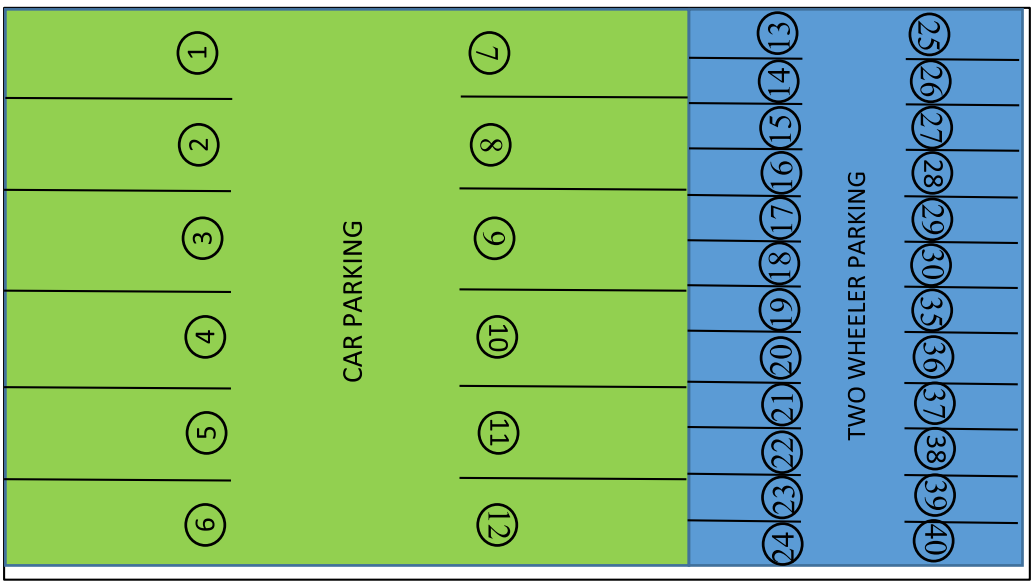

Fig. 2. Sample Layout of the Parking Area.

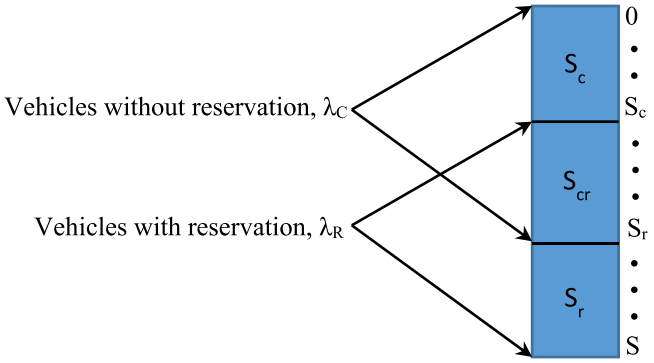

Fig. 3. System Model.

conventional parking. S_{cr} can be used by the vehicles with and without reservation. S_r can used by the vehicles, which have reservation.

If P(i) is the probability of i vehicles not getting parking slot, then P(i) can be determined from the state diagram shown in Fig. 4. The state balance equations can be obtained as

$$i\mu_C P(i) = (\lambda_C)P(i-1),\ 0 \le i \le S_c \tag{2}$$

$$i(\mu_C + \mu_R)P(i) = (\lambda_C + \lambda_R)P(i-1),\ S_c < i \le S_r \tag{3}$$

$$i\mu_R P(i) = (\lambda_R)P(i-1),\ S_r < i \le S \tag{4}$$

It is well known that the sum of all probabilities is always equal to 1.

$$\sum_{i=0}^{S} P(i) = 1 \tag{5}$$

The steady state probability P(i) can be obtained as:

$$P(i) = \begin{cases} \frac{(\lambda_C^i)}{i!\mu_C^i}P(0) & 0 \le i \le S_c \\ \frac{(\lambda_C+\lambda_R)^i}{i!(\mu_C+\mu_R)^i}P(0) & S_c < i \le S_r \\ \frac{(\lambda_R^i)}{i!\mu_R^i}P(0) & S_r < i \le S \end{cases} \tag{6}$$

Where,

$$P(0) = \left[\sum_{i=0}^{S_c}\frac{(\lambda_C^i)}{i!\mu_C^i} + \sum_{i=S_c+1}^{S_r}\frac{(\lambda_C+\lambda_R)^{i-S_c}\lambda_C^{S_c}}{i!(\mu_C+\mu_R)^{i-S_c}\mu_C^{S_c}} + \sum_{i=S_r+1}^{S}\frac{(\lambda_C+\lambda_R)^{S_r-S_c}\lambda_C^{S_c}\lambda_R^{i-S_r}}{i!(\mu_C+\mu_R)^{S_r-S_c}\mu_C^{S_c}\mu_R^{i-S_r}}\right]^{-1} \tag{7}$$

The probability with which the vehicles do not get parking slot when they do not have reservation is given as:

$$P_{NR}(C) = \sum_{i=S_r+1}^{S} P(i) \tag{8}$$

The probability with which the vehicles do not get reservation is given as:

$$P_R(R) = \frac{(\lambda_C+\lambda_R)^{S_r-S_c}\lambda_R^{S-S_r}}{S!(\mu_C+\mu_R)^{S_r-S_c}\mu_R^{S-S_r}}P(0) \tag{9}$$

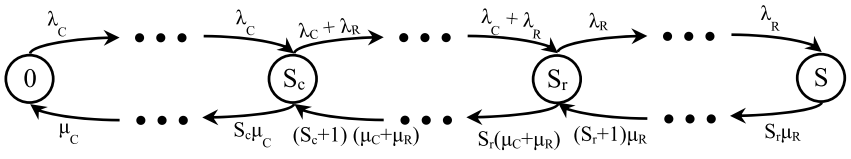

Fig. 4. State Diagram for Fig. 3.

Table 2
Simulation parameters.

Parameters	Value
Inter-arrival time amid the vehicles	5, 10, 15, 20, 25, 30
The Time for which the vehicles are parked	random
No. of car parking slots	50
No. of two wheeler parking slots	25
No. of vehicles arriving at the parking area	40, 50, 60, 70, 80, 90, 100
% of Conventional parking	20, 25, 30, 35, 40
% of Common parking slots (for both reserved and Conventional parking)	20, 25, 30, 35, 40
Reward constant	0.1
Penalty constant	0.1

6. Results and analysis

The scenario of parking area shown in Fig. 2 is simulated using Arena [27]. The arrival process of the vehicles is considered to be following the Poisson distribution. The simulation is executed for 3 hrs as the maximum limit is considered as the duration of a movie and also the shopping can be completed in maximum of 3 hrs, other than in exceptional cases. In movie theatres, the inter-arrival time will be less than 5 min whereas in shopping malls, the inter-arrival time varies depending on the time, month, etc. Hence, the parameters considered for the simulation are on average or probability basis and are shown in Table 2.

The parameters considered to test and evaluate the performance of the proposed system, LA-RSSPS are average waiting time, search time, the probability with which the vehicles do not get parking slot when they do not have reservation, and the probability with which the vehicles do not get reservation vs Number of Vehicles. Average waiting time is critical parameter which actually measures the efficiency of the system. It is measured with varying number of vehicles, with varying% of conventional parking and with varying inter-arrival time amid the vehicles as shown in Figs. 5–7, respectively. The probability with which the vehicles do not get parking slot when they do not have reservation with varying number of vehicles is shown in Fig. 8 and the probability with which the vehicles do not get reservation with varying number of vehicles is shown in Fig. 9. The performance of the proposed algorithm, LA-RSSPS is compared with the competing schemes ProNet [14] and iERS [36] and our scheme proved to be performing better than ProNet and also iERS. The performance of the proposed algorithm, LA-RSSPS is better when compared to ProNet and iERS [36] because of the involvement of time limit for which the reservation is valid. This factor eliminates the wastage of the slot reserved and not utilised. Goodput value of the vehicles/user plays important role to make the system more attractive as it guarantees the parking slot for a regular customer.

It can be observed from the Fig. 5 that average waiting time increases with the increase in the number of vehicles. The performance of LA-RSSPS is on the average better than ProNet by 83%, iERS by 73.5%. The proposed algorithm, LA-RSSPS is performing better than ProNet and iERS because the parking area is divided into conventional parking, reserved parking and parking for vehicles with and without reservation. The average inter-arrival time amid the vehicles is considered to be 10 min in this case. The% of conventional parking is considered to be 25% and percentage of parking for vehicles with and without reservation is considered to be 20% and the remaining is for the vehicles with reservation. Moreover, as the proposed system, LA-RSSPS, is maintaining the goodput value of the vehicles, the performance is increased.

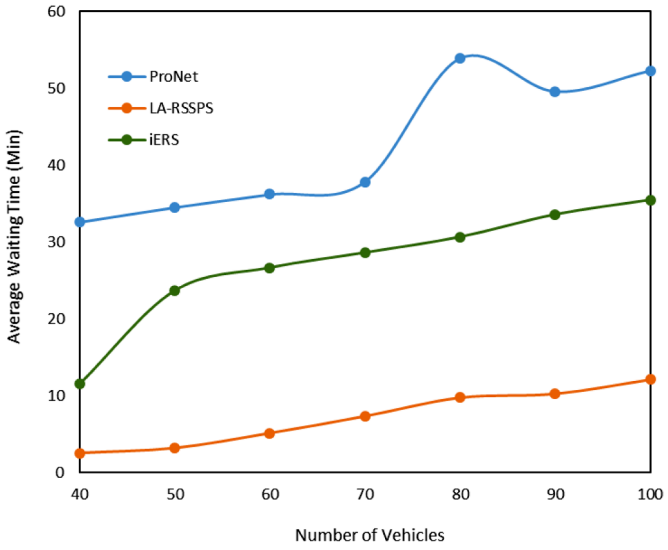

Fig. 5. Average Waiting Time vs Number of Vehicles.

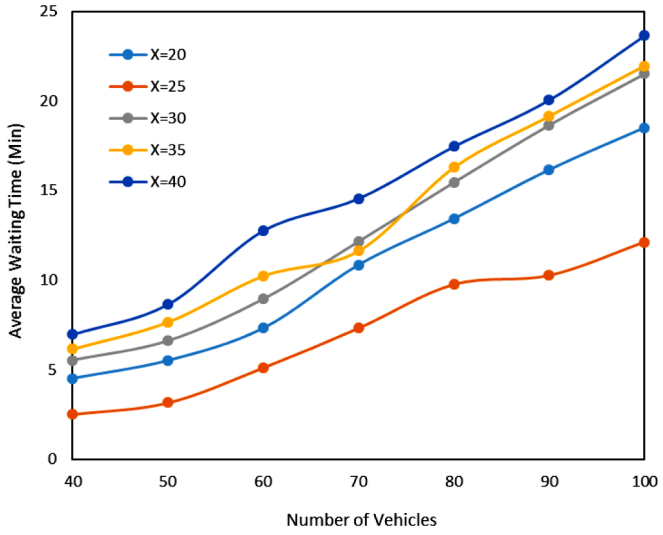

Fig. 6. Average Waiting Time vs Number of Vehicles.

Fig. 6 shows the performance of the proposed algorithm, LA-RSSPS, in terms of average waiting time with varying number of vehicles. Here, the performance is evaluated for different% of conventional parking in the parking area. In this case, the% of parking area for the vehicles with and without reservation is considered as 30%. Thus, the% of parking area for reservation of parking slots is varied with% of conventional parking. It can be observed that the performance is better when% of conventional parking is 25%. Therefore, with S_c = 25%, S_{cr} = 30% and S_r = 45%, the system gives us better performance. The average inter-arrival time amid the vehicles is considered to be 10 min in this case.

The performance of the proposed algorithm, LA-RSSPS is compared with ProNet and iERS in terms of average waiting time with varying inter arrival time of vehicles and it is shown in Fig. 7. It can be observed from Fig. 7 that the performance of LA-RSSPS is 77.2% better when compared to ProNet and 43.5% better when compared to iERS. In this case, the number of vehicles is considered as 100, S_c is 25%, S_{cr} is 30% and S_r is 45%. The time period for which the vehicles will be in the parking area is random.

The simulation results and analytical results of the proposed system, LA-RSSPS are compared in terms of the probability with which the vehicles do not get parking slot when they do not have reservation with varying number of vehicles and is shown in Fig. 8.

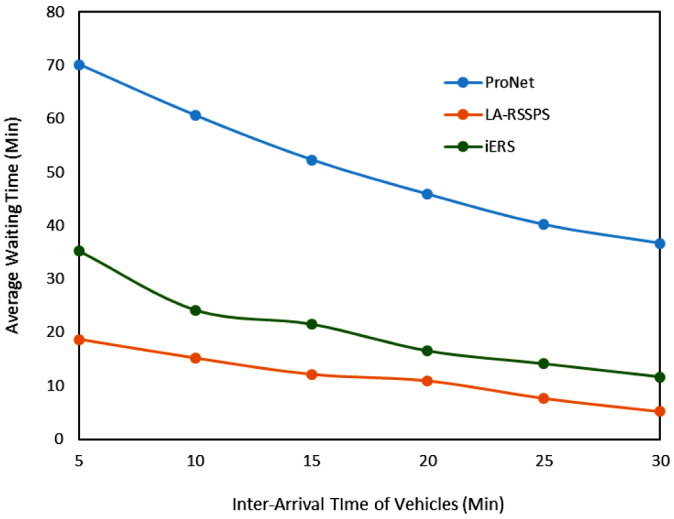

Fig. 7. Average Waiting Time vs Inter-Arrival Time of Vehicles.

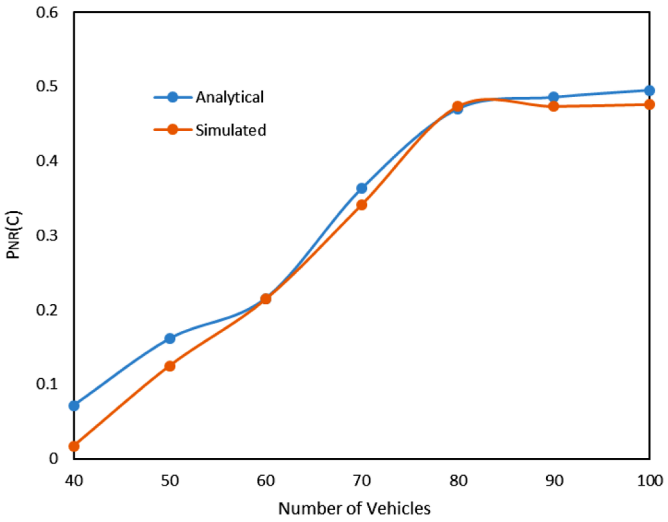

Fig. 8. The probability with which the vehicles do not get parking slot when they do not have reservation vs Number of Vehicles.

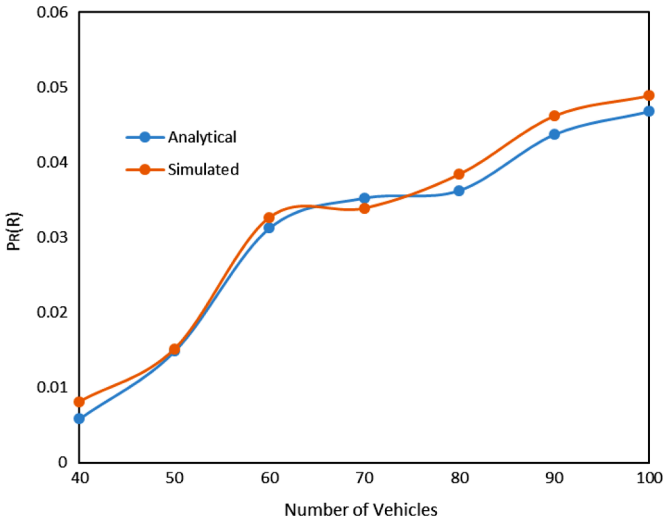

Fig. 9. The probability with which the vehicles do not get reservation vs Number of Vehicles.

The simulation results and analytical results of the proposed system, LA-RSSPS are compared in terms of the probability with which the vehicles do not get reservation with varying number of vehicles and is shown in Fig. 9. It can be observed from Fig. 8 and Fig. 9 that the simulation and analytical results are close to each other. In this case, S_c is 25%, S_{cr} is 30% and S_r is 45%. The time period for which the vehicles will be in the parking area is random. The average inter-arrival time amid the vehicles is considered to be 10 min in this case. This gives good validity to our simulation model.

Fig. 10 shows the performance of the proposed protocol, LA-RSSPS in terms of search time for every hour in a day in comparison with ProNet and iERS. It can be observed that the performance of the proposed protocol is better when compared to ProNet and iERS which indicates that the time to search for a parking slot is less in the case of the proposed algorithm, LA-RSSPS. The parameter, search time is effective in case of LA-RSSPS as the reservation is going to be made by the people and some portion of parking area is reserved for the conventional parking.

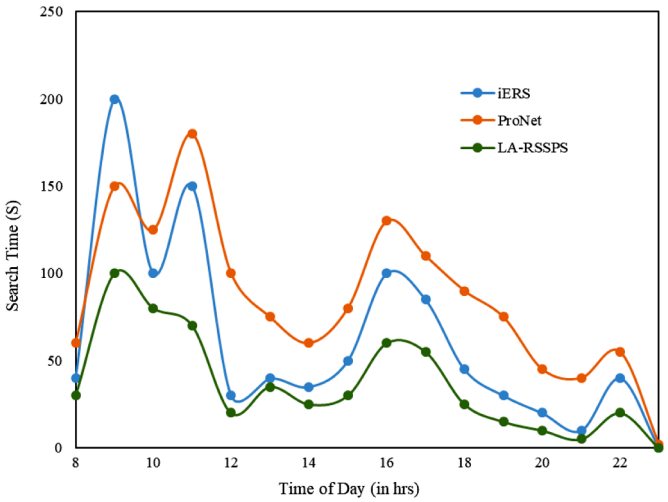

Fig. 10. Search time vs Time of Day (in hrs).

7. Conclusions

This paper proposed the Learning Automata and Reservation based Secure Smart Parking System (LA-RSSPS). The parking area is partitioned into conventional parking, reservation based parking and integrated part. The% of conventional parking is determined using learning automata. Security for the user details provided during reservation of the parking slot is provided using encryption process. The user can reserve the parking slot before they reach the destination. A Parameter referred as Goodput value is maintained for every vehicle, which increases or decreases the chances of obtaining a reservation slot. The time limit is set out once the reservation is done and automatically expires in order to disable the reserved parking slot. The Markov Model is used to represent the system. The average waiting time is critical parameter in smart parking system, which the performance of the proposed system, LA-RSSPS is tested, compared with competing schemes, ProNet and iERS, and proved to be performing better. The performance of the proposed system, LA-RSSPS is also evaluated in terms of the probability with which the vehicles do not get parking slot when they do not have reservation and the probability with which the vehicles do not get reservation. The comparison of analytical and simulations results are also projected and simulation model was validated by the analytic model.

References

[1] I.F. Akyildiz, X. Wang, W. Wang, Wireless mesh networks: a survey, Comput. Netw. 47 (4 March) (2005) 445_487.
[2] C. Rhodes, W. Blewitt, C. Sharp, G. Ushaw, G. Morgan, Smart routing: a novel application of collaborative path-finding to smart parking systems, Proc. IEEE 16th Conf. Bus. Infom, 2014, p. 119_126 Jul..
[3] N. Mejri, M. Ayari, R. Langar, F. Kamoun, G. Pujolle, L. Saidane, Cooperation versus competition towards an efficient parking assignment solution, Proc. IEEE Int. Conf. Commun, Sydney, NSW, Australia, 2014, p. 2915_2920 Jun..
[4] Y. Atif, J. Ding, M.A. Jeusfeld, Internet of things approach to cloud-based smart car parking, Procedia Comput Sci 98 (2016) 193–198.
[5] A. Zanella, N. Bui, A. Castellani, L. Vangelista, M. Zorzi, Internet of things for smart cities, IEEE Internet Thing. J. 1 (1) (2014) 22–32.
[6] D. Teodorovic, P. Lucic, Intelligent parking systems, Eur. J. Oper. Res. 175 (3) (2006) 1666–1681.
[7] SFpark. [Online]. Available: http://sfpark.org.
[8] H. Takizawa, K. Yamada, T. Ito, Vehicles detection using sensor fusion, Intelligent Vehicles Symposium, IEEE, 2004, pp. 238–243 2004.
[9] S. Funck, N. Mohler, W. Oertel, Determining car-park occupancy from single images, Intelligent Vehicles Symposium, IEEE, 2004, pp. 325–328 2004.
[10] D. Bong, K. Ting, K. Lai, Integrated approach in the design of car park occupancy information system (COINS), IAENG Int. J. Comput. Sci. 35 (1) (2008) 7–14.
[11] J. Wolff, T. Heuer, H. Gao, M. Weinmann, S. Voit, U. Hartmann, Parking monitor system based on magnetic field sensor, In 2006 IEEE Intelligent Transportation Systems Conference, IEEE, 2006, pp. 1275–1279 September.
[12] Z. Pala, N. Inanc, Smart parking applications using RFID technology, 2007 1st Annual RFID Eurasia, IEEE, 2007, pp. 1–3 September.
[13] M.S. Jian, K.S. Yang, C.L. Lee, Modular RFID parking management system based on existed gate system integration, WSEAS Trans. Syst. 7 (2008) 706–716.
[14] T.N. Pham, M.F. Tsai, D.B. Nguyen, C.R. Dow, D.J. Deng, A cloud-based smart-parking system based on Internet-of-Things technologies, IEEE Access 3 (2015) 1581–1591.
[15] Y. Geng, C.G. Cassandras, New “smart parking” system based on resource allocation and reservations, IEEE Trans. intell. Transport. Syst. 14 (3) (2013) 1129–1139.
[16] M. Gallo, L. D'Acierno, B. Montella, A multilayer model to simulate cruising for parking in urban areas, Transp. Policy 18 (5 September) (2011) 735–744.
[17] I. Benenson, K. Martens, S. Birr, Parkagent: an agent-based model of parking in the city, Comput. Environ. Urban Syst. 32 (6 November) (2008) 431–439.
[18] J. Polak, K.W. Axhausen, Clamp: a macroscopic simulation model for parking policy analysis, presented at the 68th Annu. Meeting Transp. Res. (1989).
[19] W. Young, Parksim 1.1 User's Manual, Department of Civil Engineering. Melbourne, Monash Univ, VIC, Australia, 1991.
[20] C.J. Rodier, S.A. Shaheen, Transit-based smart parking: an evaluation of the San Francisco bay area field test, Transp. Res. C, Emerging Technol 18 (2 April) (2010) 225–233.
[21] T.B. Hodel, S. Cong, Parking space optimization services, a uniformed web application architecture, in Proc. ITS World Congr (2003) 16–20.
[22] I. Kumar, P. Manuja, Y. Soni, N.S. Yadav, An integrated approach toward smart parking implementation for smart cities in India, Advances in Data and Information Sciences, Singapore, Springer, 2020, pp. 343–349.
[23] H. Wang, W. He, A reservation-based smart parking system, In 2011 IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), IEEE, 2011, pp. 690–695. April.

[24] A. Nath, H.N. Konwar, K. Kumar, M.R. Islam, Technology enabled smart efficiency parking system (TESEPS), Trends in Communication, Cloud, and Big Data, Singapore, Springer, 2020, pp. 141–150.
[25] da Cruz, M. A., J.J. Rodrigues, G.F. Gomes, P. Almeida, R.A. Rabelo, N. Kumar, S. Mumtaz, An IoT-based solution for smart parking, In Proceedings of First International Conference on Computing, Communications, and Cyber-Security (IC4S 2019), Singapore, Springer, 2020, pp. 213–224.
[26] M. Sarangi, S. Mohapatra, S.V. Tirunagiri, S.K. Das, K.S. Babu, IoT aware automatic smart parking system for smart city, Cognitive Informatics and Soft Computing, Singapore, Springer, 2020, pp. 469–481.
[27] https://www.arenasimulation.com/.
[28] S. Tanwar, S. Tyagi, N. Kumar, M.S. Obaidat, LA-MHR: learning automata based multilevel heterogeneous routing for opportunistic shared spectrum access to enhance lifetime of WSN, IEEE Syst. J. 13 (1) (2018) 313–323.
[29] J. Ren, G. Wu, X. Su, G. Cui, F. Xia, M.S. Obaidat, Learning automata-based data aggregation tree construction framework for cyber-physical systems, IEEE Syst. J. 12 (2) (2016) 1467–1479.
[30] P.V. Krishna, S. Misra, D. Nagaraju, V. Saritha, M.S. Obaidat, Learning automata based decision making algorithm for task offloading in mobile cloud, In 2016 International Conference on Computer, Information and Telecommunication Systems, CITS, IEEE, 2016, pp. 1–6 July.
[31] P.V. Krishna, S. Misra, V. Saritha, D.N. Raju, M.S. Obaidat, An efficient learning automata based task offloading in mobile cloud computing environments, In 2017 IEEE international conference on communications, ICC, IEEE, 2017, pp. 1–6 May.
[32] H. Most faei, M.S. Obaidat, Learning automaton-based self-protection algorithm for wireless sensor networks, IET Netw. 7 (5) (2018) 353–361.
[33] V. Saritha, P.V. Krishna, S. Misra, M.S. Obaidat, Learning automata-based channel reservation scheme to enhance QoS in vehicular adhoc networks, In 2016 IEEE global communications conference, GLOBECOM, IEEE, 2016, pp. 1–6 December.
[34] V. Saritha, P.V. Krishna, S. Misra, M.S. Obaidat, Learning automata based optimized multipath routing using leapfrog algorithm for VANETs, In 2017 IEEE International Conference on Communications (ICC), IEEE, 2017, pp. 1–5 May.
[35] H. Trivedi, S. Tanwar, P. Thakkar, Software defined network-based vehicular adhoc networks for intelligent transportation system: recent advances and future challenges, Futur. Trend. Netw. Commun. Technol. (2018) 325–337, https://doi.org/10.1007/978-981-13-3804-5_24.
[36] V. Chauhan, M. Patel, S. Tanwar, S. Tyagi, N. Kumar, IoT Enabled real-time urban transport management system, Comput. Electr. Eng. 86 (2020) 106746.
[37] S. Tyagi, S. Tanwar, N. Kumar, Learning automata-based coverage oriented clustering in HWSNs, In 2015 Second International Conference on Advances in Computing and Communication Engineering, IEEE, 2015, pp. 78–83 May.
[38] K. Chauhan, S. Jani, D. Thakkar, R. Dave, J. Bhatia, S. Tanwar, M.S. Obaidat, Automated machine learning: the new wave of machine learning, In 2020 2nd International Conference on Innovative Mechanisms for Industry Applications (ICIMIA), IEEE, 2020, pp. 205–212 March.
[39] D. Patel, Z. Narmawala, S. Tanwar, P.K. Singh, A systematic review on scheduling public transport using IoT as tool, Smart Innovations in Communication and Computational Sciences, Singapore, Springer, 2019, pp. 39–48 ,.
[40] J. Oza, Z. Narmawala, S. Tanwar, P.K. Singh, Public transport tracking and its issues, Int. J. Comput. Sci. Eng. 5 (11) (2017).
[41] Mewada, A., Tanwar, S., & Narmawala, Z. (2018, December). Comparison and evaluation of real time reservation technologies in the intelligent public transport system. In 2018 Fifth International Conference on Parallel, Distributed and Grid Computing (PDGC) (pp. 800-805). IEEE.