Efficient automated car parking system based modified internet of spatial things in smart cities

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Article Info

ABSTRACT

The technological advances of smart cities have been progressively increasing to improve the quality of life to humans, especially in urban mobility. Parking appears to be a major issue, with residents needing to find a suitable parking space among many parking areas, resulting in time and fuel waste as well as environmental pollution. We propose in this paper a new automated system model that integrates reinforcement learning (RL), Q-learning, and image processing algorithms based on modified internet of spatial things (IoST) architecture to optimize automated parking in smart cities. For demonstrating the efficiency of the proposed model, iFogSim simulation is used to reduce network usage and latency. Moreover, it deploys heterogeneous devices in multi layers and different scenarios. The experimental results show that the suggested system for automated car parking in fog-based placement-IoST network is feasible and effective. It minimizes latency and the total network usage compared to the cloud-based placement of the implemented system.

Keywords:
Cloud-based placement
Fog-based placement
Internet of spatial things
Load balancing
Q-learning

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1. INTRODUCTION

The development of smart cities has emerged as a trend worldwide. It utilizes information and communication technologies to raise the citizens' quality of life and their interactions with the government. Therefore, one of the main issues with urban development is the amount of traffic and urban mobility. They encounter numerous obstacles to sustainable mobility due to the city's transportation, traffic, and parking systems' capacity issues, as well as the rising demand for parking systems [1].

The internet of things (IoT) is used to reduce the traffic problem and vehicle parking congestion. IoT is a rapidly evolving technology that allows devices to connect and exchange data with one another. It comprises various "devices" with internet connectivity and networking capabilities [2]. Researchers have created a number of IoT-based online and remote monitoring systems as in [3], which help the driver to find available parking space. It suggested a technique that was deployed online using a website application, helping users locate free parking spaces. Since the system had an ultrasonic sensor, it served as a detector that transmitted information to the microcontroller for updating into the cloud server for access to the data. Using the IoT, researchers in [4] proposed a smart parking system using field-programmable gate arrays (FPGA) depending on emergency status. Singh and Vaidya [5] proposed an automated vehicle parking system to identify the license plate number to manage vehicle billing and parking by using image processing. While authors used one of the fundamental machine learning methods, kernel nearest neighbors (KNN), to recognize the license plate [6]. Introduced a smart vehicle parking system using fog computing in IoT environments [7], [8].

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Recently, parking is a challenging task for drivers, particularly for new ones. Thus, machine learning (ML) emerged as a promising solution due to its adaptability to learning and working in a different environment [9]. Reinforcement learning, namely Q-learning, is an important type of machine learning. It is used to determine the optimal action-selection policy for any state [9], [10]. Therefore, it is used for designing automated parking as in [11]. Lai [9] proposed an automated car parking system based on Q-learning which is a reinforcement learning technique. However, the system did not cover its effectiveness in detail such as delay and energy awareness. Shoeibi and Shoeibi [12] proposed automatic valet parking using hybrid robotic valets in smart parking. It employs a reinforcement learning technique, namely deep Q-learning, to reach effective performance. However, the system needs to speed up and consider effective power consumption. Min et al. [13] introduced a parking guidance system that utilizes the Q-learning resource allocation model in an IoT environment. Though the simulation results show effectiveness in throughput and response time, the simulation procedure has inconsistencies. Hasan et al. [14] devised an AI-based parking recommendation model using Q-learning and cloud computing model in addition to amazon web service (AWS) IoT. The system helps to speed up the data transfer and latency reduction in the system.

It is expected that within years the number of things in IoT will reach billions [15]. According to experts, an object’s spatial characteristics are defined by where it is located on the earth [16]. Internet of spatial things (IoST) is a paradigm that integrates embedded smart devices and is focused on gathering spatial information about objects [17]. The IoST creates a large amount of data over a period of time. Thus, the load balancing protocol is an important factor in the development of IoST. The fundamental objective of the load balancing approach is to improve the execution speed of activities by making better use of the available resources, whose capacity for jobs varies irregularly over run time. Kim and Kim [18] advised load balancing protocol in IoT using Q-learning and neural prior ensemble. Jena et al. [19] suggested the QMPSO scheme which is integrating improved Q-learning with modified particle swarm optimization (MPSO) to enhance the load balancing in the cloud environment. The suggested technique also efficiently minimizes task waiting times while increasing makespan, throughput, and energy consumption during load balancing. Roh et al. [20] proposed a load balancing routing protocol using a Q-learning algorithm for an unmanned aerial vehicle (UAV)-assisted vehicular ad hoc network (VANET). Tosounidis et al. [21] proposed a traffic load balancing scheme in software-defined networking (SDN) based on CNN and Q-learning to precisely choose the server that is most suited to process requests from SDN applications. Different studies have discussed load balancing strategies, such as static load balancing and dynamic load balancing, in both heterogeneous and homogeneous environments [19]. Despite few studies for example [20], [22]–[24] have taken into account load balancing routing protocols to resolve both complex dynamic networks and traffic growth in the future, most routing protocols do not consider traffic load balancing [25], [26].

Much of the IoT research up to now has been built in cloud-based IoT model. The centralized solution of cloud computing (CC) might not be efficient to handle with anticipated enormous volume of data. Thus, fog computing (FC) was devised as a novel solution to address the IoT’s emerging problems close to things effectively [15]. Besides that in IoT architecture, accurate analysis of spatial data would produce crucial information [27]. Typically, IoST is support important applications e.g., smart transportation, smart cities, smart agriculture, and military applications [28]. Thus, this study is proposed to solve the problems of IoT automated parking systems in smart cities, especially in terms of time and network usage, with the following contributions:

- a) Build a fog computing-based IoST framework which consists of three layers. layer-1 represents spatial data sources, IoST fog computing is deployed in the middle layer where the parking slot images are processed, and layer-3 represents the cloud layer to achieve an efficient automated parking system considering the latency and network usage.
- b) Deploy distributed smart camera networks at layer-1 to achieve intelligent surveillance.
- c) Modify the IoST by employing Q-learning (off-policy) at the fog layer to achieve load balancing in IoST network.
- d) Apply image processing technique on the captured images data to detect the vacant parking slots.
- e) Then the parking slot information is displayed on the respective parking area’s LED. The drivers are guided to the vacant parking slot at the entrance gate of the car park to minimize traffic congestion and waste of fuel.
- f) Assess the efficiency and efficacy of fog-based placement automated parking design through the simulation. Experimental analyses show a considerable decrease in latency and network utilization in comparison to the automated parking system's cloud-based placement.

This paper is organized in the following way. Section 2 presents the proposed method with its architecture, algorithm which includes its functioning, and experimental setup used to implement the proposed research method. Section 3 analyses the results. Section 4 concludes the paper and suggests future research directions.
2. RESEARCH METHOD
2.1. Proposed system architecture

In this section, the proposed architecture of a reference fog-based IoST model for automated parking system comprises three layers as illustrated in Figure 1. Layer 1 has intelligent cameras, microcontroller devices, and LEDs. Intelligent cameras are distributed above the parking spaces or lanes that are in charge of taking images of the slots. Fog nodes are deployed in layer 2, which is linked to the cameras through microcontrollers. The proposed method deploys at this layer. Smart LEDs display the parking lanes’ status. Layer 3 represents the cloud layer and is in charge of handling and storing the frame data for longer periods. The nearest parking space is shown on the LED screen when the car arrives at the parking site.

![Figure 1. Fog-based IoST architecture for automated parking system](image)

2.2. Implementation of proposed method

This section explains the methodology used to detect the nearest empty slot for car parking. Firstly, distributed cameras are deployed to cover their field of view (FOV). It captures images of the parking slots. When new data arrives to fog, the Q-learning approach from Reinforcement Learning is applied to suggest a new network load learning technique on the data. Next, it processes to extract the data by image processing technique. Then, based on Q-learning and image processing techniques the free parking slots are set. Every five seconds, the fog node receives images from cameras and updates the parking status display. Algorithm 1 describes the flow of detecting the nearest empty slot for parking. Consider S is a set of states in the environment and each state has a set of actions A. An agent selects an action (a) at time t in the state to transit to the next state through the transition process and receive a reward or penalty. Based on the obtained R, reward or penalty, the Q-value is continually updated. The most appropriate path for a car is considered the states with the highest Q-value.

Algorithm 1. Automated detecting vacant parking slot algorithm

**Algorithm:** Detecting Vacant Parking Slot

**Input:** Parking Slot Images

**Output:** Parking Slots Information

1. Initialize the system:
   - Set cameras stationary
   - Capture the image of parking area

2. For each execution sequence (every transmission time) as the following:

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a) Apply RL with Q-learning on the data to achieve load balance
   set Parameters: step size $\alpha \in (0, 1]$, Discount factor $\gamma \in [0, 1]$;
   Initialize $Q(s, a) \forall s \in S^t, a \in A(s)$ arbitrarily;
   While ($Q$ is not converged) do
      For each step of the episode do
         Initialize $S$;
         For each step of the episode:
            Choose $A$ from $S$ using policy derived from $Q$ (eg., $\epsilon$-greedy);
            Take action $A$, observe $R$, $S'$;
            $Q(S, A) \leftarrow Q(S, A) + \alpha [R + \gamma \max_a Q(S', a) - Q(S, A)]$;
         $S \leftarrow S'$;
      end
   return $Q$

b) Apply image processing technique on the image data to find a vacant parking slot
   Image segmentation
   Image enhancement
   Image detection

3. Return result

2.3. Experimental setup

In this section, our proposed automated car parking system for smart cities is deployed using the iFogSim [29], [30] simulator. The simulation tool support deploying the system with two architectures, cloud-based and fog-based deployment. Cloud-based placement strategy is where all of the functionalities perform in the cloud. In this case, cameras send their spatial data to the cloud for the process. While in fog-based placement, the functionalities perform in the fogs of the network. The simulated scenario involved smart cameras taking images and sending the data to the fog every five seconds. The responsible fog node receives the data and processes them to determine the vacant slots by deploying image processing after balancing the load among nodes using Q-learning. The fog sends the status of the slot to the LED through wifi connection. On the other hand, the fogs connect to the cloud using the proxy server. Since the smart cameras are equipped with wifi and connected using a microcontroller, we simulated them as sensors.

Fog-based architecture has been illustrated in Figure 2 for simulating a physical topology of one cloud, one proxy server, fog nodes range from one to twelve, and each fog node has 4 cameras and one LED. Due to the computations being done on the fog nodes, cloud computation is much reduced. Though, utilizing a router to connect the cameras directly to the cloud server causes higher latency and hence excessive network usage. The specification parameters of the fog-based infrastructure are presented in Table 1.

Figure 2. Topology of 8 cameras connected to 2 fog nodes connected to the cloud server through the proxy server
On the other hand, the cloud-based architecture has been illustrated in Figure 3. For simulating multiple numbers of cameras that up to 48 cameras and LED are connected to the cloud via a proxy server. Cameras capture the car parking slots and passed them to the cloud using the router. The cloud server processes the slot images and then passes the status of the slots to the LED. Table 2 illustrates the specification of the cloud-based parameters.

### Table 1. Simulation parameters of fog-based placement scenario

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Cloud</th>
<th>Proxy</th>
<th>Fog</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU length (MIPS)</td>
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<td>RatePerMIPS</td>
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<td>RAM (MB)</td>
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<td>Uplink bandwidth (MB)</td>
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<td>1,000</td>
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<tr>
<td>Downlink bandwidth (MB)</td>
<td>10,000</td>
<td>10,000</td>
<td>10,000</td>
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<tr>
<td>Busy power (Watt)</td>
<td>16*103</td>
<td>107.339</td>
<td>107.339</td>
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<tr>
<td>Idle power (Watt)</td>
<td>16*83.25</td>
<td>83.4333</td>
<td>83.4333</td>
</tr>
</tbody>
</table>

![Figure 3. Topology of cloud-based architecture with 8 cameras connected through a proxy server](image)

### Table 2. Simulation parameters of cloud-based placement scenario

<table>
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<th>Router</th>
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</table>

### 3. RESULTS AND DISCUSSION

This section evaluates the efficiency of the suggested automated car parking based on modified IoST for smart cities on two placement techniques, fog-based and cloud-based placement, then compares their results considering latency and network usage. Experimental results illustrate that deploying our system with fog-based architecture is more efficient than with the cloud-based architecture in terms of latency and network usage for various simulation scenarios as illustrated in Figure 4. In fog-based placement, each fog node is specifically designated to process the images for its area only and avoids frequent cloud accesses. Contrarily, in the case of cloud computing, a cloud server processes all of the parking area images, and as a result, the latency rises as the number of cameras increases as illustrated in Figure 4(a). In addition, forwarding all the data from the cameras to the cloud increases network traffic which increases the use of the network in the cloud-based model as illustrated in Figure 4(b).
4. CONCLUSION

In smart cities, designing an efficient automated car parking system is considered a crucial part of the city management system. The main objective of this study is to develop automated car parking for smart cities. It combined reinforcement learning, Q-learning, and image processing algorithms in IoT architecture to find available parking spaces. Besides this, it distributed heterogeneous devices in multiple layers and scenarios. The proposed study verified two architectures, fog-based and cloud-based placement using iFogSim simulator. The result shows the efficiency of the proposed techniques in fog-based modified IoT model in respect of time and cost of network execution. In the future, we would like to add privacy to the saved data in the cloud using encryption algorithms. Moreover, there is also a demand to integrate geographic information system (GIS) technologies into the proposed system that enable high throughput analysis of spatial data streams and offer data visualization. In addition, we suggest evaluating the energy consumption of the proposed system.

REFERENCES

BIOGRAPHIES OF AUTHORS

Noor Alsaedi received the B.Sc. degree in computer engineering from the University of Technology, Iraq, in 2006, the M.Sc. degree in wireless communication and network engineering from the Universiti Putra Malaysia (UPM), Malaysia, in 2016. She is currently a Ph.D. student in the department of information and communication engineering, Collage of Information Engineering, Iraq. Her research interests include resource management and internet of things. She can be contacted at email: nlight1124@gmail.com.

Ali Sadeq Abdulhadi Jalal was born in 1958 in Baghdad—the capital city of the Republic of Iraq. He earned the bachelor and master degrees in electrical and communication engineering at Al-Rasheed College for Engineering and Science, University of Technology, Baghdad, Iraq in 1980 and 1986 respectively. From that date, he was appointed as an assistant lecturer in the field of electronics and communication engineering in the same college. He was awarded the lecturer and assistant professorships in 1994 and 2009 respectively. He finished his Ph.D. at University Putra Malaysia (UPM) in 2013. He is now a professor at Al-Nahrain University/College of Information Engineering. His main research interests are in electronics; analog and digital, antennas and microwave devices. He can be contacted at email: alijalal@nahrainuniv.edu.iq or asajalal@yahoo.com.