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

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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.

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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].

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.

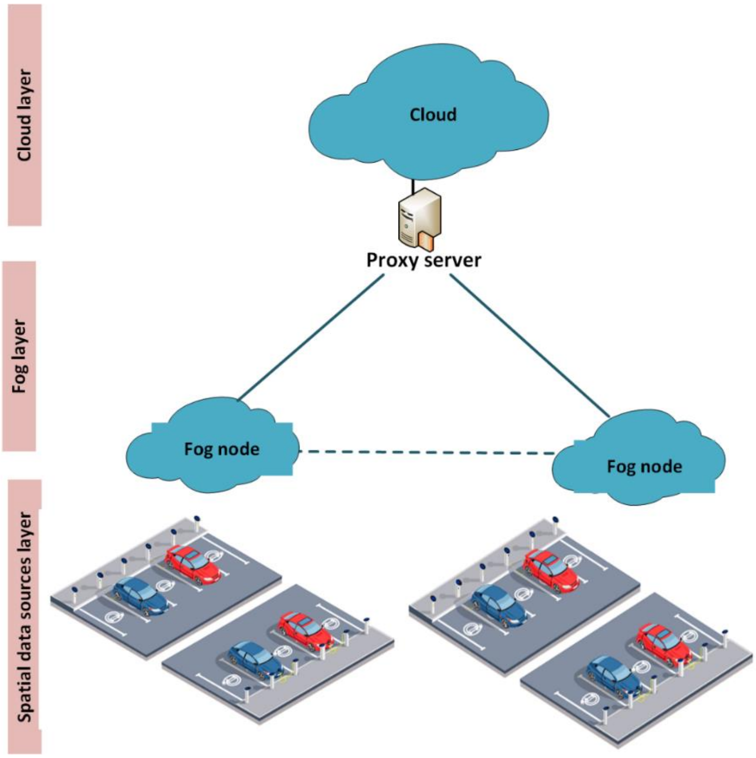

Figure 1. Fog-based IoST architecture for automated parking system

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 α ∈ (0,1], Discount factor γ ∈ [0, 1];
        Initialize Q(s,a) ∀ s ∈ S⁺, a ∈ A(s) arbitrarily;
        While (Q is not converged ) do
        For each episode do
                Initialize S ;
                For each step of the episode:
                        Choose A from S using policy derived from Q (eg., ε - greedy);
                        Take action A, observe R, S' ;
                        Q(S,A) ← Q(S,A) + α [ R + γ Max_Q Q(S',a) − Q(S,A)];
                        S ← S' ;
                        end
                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.

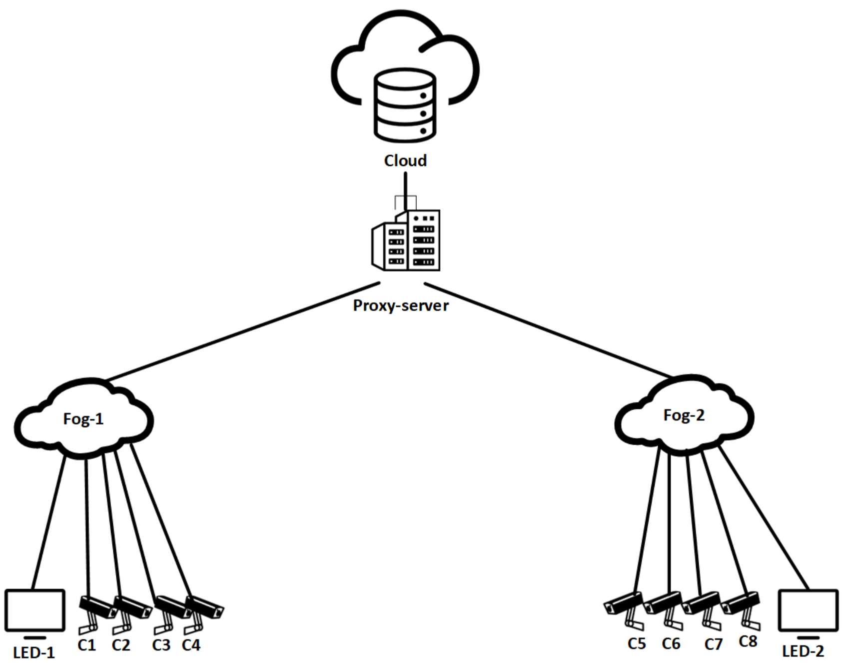


Figure 2. Topology of 8 cameras connected to 2 fog nodes connected to the cloud server through the proxy server

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

Parameters	Cloud	Proxy	Fog
CPU length (MIPS)	44,800	2,800	2,800
RatePerMIPS	0.01	0.0	0.0
RAM (MB)	40,000	4,000	4,000
Uplink bandwidth (MB)	100	10,000	1,000
Downlink bandwidth (MB)	10,000	10,000	10,000
Busy power (Watt)	16*103	107.339	107.339
Idle power (Watt)	16*83.25	83.4333	83.4333

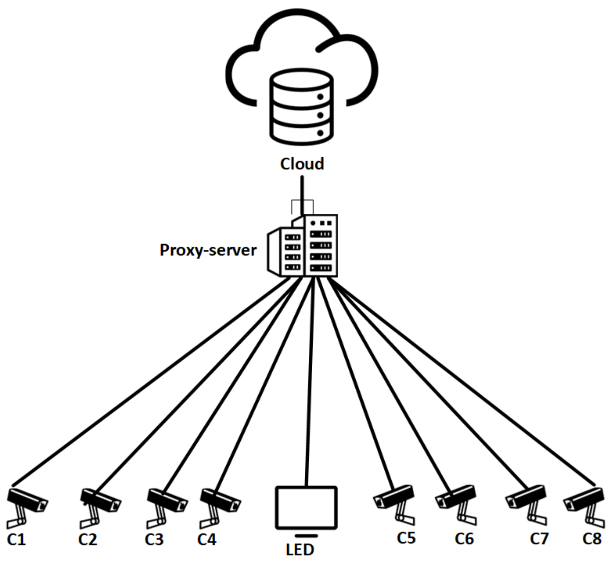


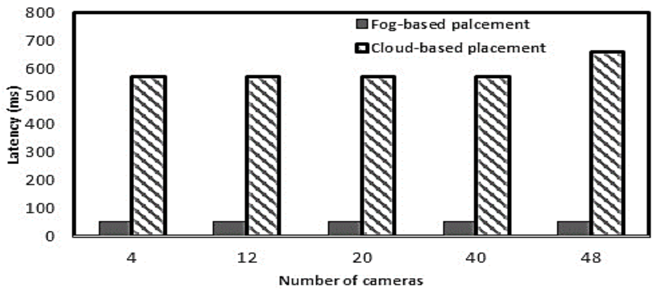
Figure 3. Topology of cloud-based architecture with 8 cameras connected through a proxy server

Table 2. Simulation parameters of cloud-based placement scenario

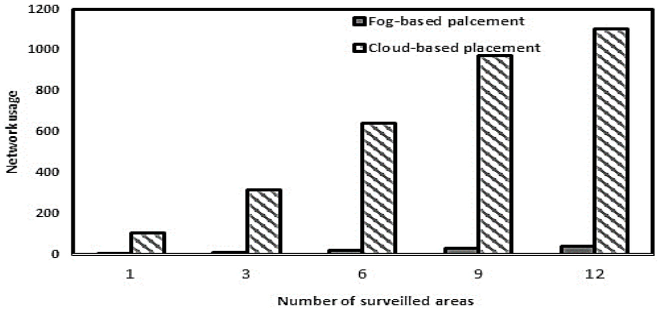
Parameters	Cloud	Router
CPU length (MIPS)	44,800	2,800
RatePerMIPS	0.01	0.0
RAM (MB)	40,000	4,000
Uplink bandwidth (MB)	100	10,000
Downlink bandwidth (MB)	10,000	10,000
Busy power (Watt)	16*103	107.339
Idle power (Watt)	16*83.25	83.4333

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).



(a)



(b)

Figure 4. Comparison in fog-based and cloud-based IoST of (a) latency and (b) network usage

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 IoST 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 IoST 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

[1] S. C. K. Tekouabou, E. A. A. Alaoui, W. Cherif, and H. Silkan, “Improving parking availability prediction in smart cities with IoT and ensemble-based model,” *Journal of King Saud University - Computer and Information Sciences*, vol. 34, no. 3, pp. 687–697, 2022, doi: 10.1016/j.jksuci.2020.01.008.

[2] S. S. Ibraheem, A. H. Hamad, and A. S. A. Jalal, “A secure messaging for internet of things protocol based RSA and DNA computing for video surveillance system,” in *2018 Third Scientific Conference of Electrical Engineering (SCEE)*, 2018, pp. 280–284, doi: 10.1109/SCEE.2018.8684055.

[3] Z. Dzulkurnain, A. K. Mahamad, S. Saon, M. A. Ahmadon, and S. Yamaguchi, “Internet of things (IoT) based traffic management and routing solution for parking space,” *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 15, no. 1, pp. 336–345, 2019, doi: 10.11591/ijeecs.v15.i1.pp336-345.

[4] K. J. Yong and M. H. Salih, “Design and implementation of embedded auto car parking system using FPGA for emergency conditions,” *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 13, no. 3, pp. 876–883, 2019, doi: 10.11591/ijeecs.v13.i3.pp876-883.

[5] A. Singh and S. P. Vaidya, “Automated parking management system for identifying vehicle number plate,” *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 13, no. 1, pp. 77–84, 2019, doi: 10.11591/ijeecs.v13.i1.pp77-84.

[6] D. A. A. Alhamza and A. D. Alaythawy, “Iraqi license plate recognition based on machine learning,” *Iraqi Journal of Information and Communications Technology*, vol. 3, no. 4, pp. 1–10, 2020, doi: 10.31987/ijict.3.4.94.

[7] K. S. Awaisi *et al.*, “Towards a fog enabled efficient car parking architecture,” *IEEE Access*, vol. 7, pp. 159100–159111, 2019, doi: 10.1109/ACCESS.2019.2950950.

[8] C. Tang, X. Wei, C. Zhu, W. Chen, and J. J. P. C. Rodrigues, “Towards smart parking based on fog computing,” *IEEE access*, vol. 6, pp. 70172–70185, 2018, doi: 10.1109/ACCESS.2018.2880972.

[9] L. Lai, “Automatic parking with Q-learning,” *In Eastern European Machine Learning Summer School*, pp. 5–7, 2021, [Online]. Available: https://leoll2.github.io/Autoparking/docs/paper_short.pdf

[10] J. Clifton and E. Laber, “Q-learning : theory and applications,” *Annual Review of Statistics and Its Application*, vol. 7, pp. 279–303, 2020, doi: 10.1146/annurev-statistics-031219-041220.

[11] D. Moreira, "Deep reinforcement learning for automated parking," pp. 1–63, 2021, [Online]. Available: https://repositorio-aberto.up.pt/bitstream/10216/136074/2/494682.pdf

[12] N. Shoeibi and N. Shoeibi, "Future of smart parking: Automated valet parking using deep Q-learning," *Advances in Intelligent Systems and Computing*, vol. 1004, no. January, pp. 177–182, 2020, doi: 10.1007/978-3-030-23946-6_20.

[13] D. J. Min, D. S. Kim, and H. H. Choi, "Design and Implementation of parking guidance system based on internet of things (IoT) using Q-learning model," *IEMEK Journal of Embedded Systems and Applications*, vol. 11, no. 3, pp. 153–162, 2016, doi: 10.14372/IEMEK.2016.11.3.153.

[14] M. Hasan, K. R. Ahmed, and M. Islam, "Parking recommender system using Q-learning and cloud computing," in *International Conference on Cyber Security and Computer Science*, 2020, pp. 607–618, doi: 10.1007/978-3-030-52856-0_48.

[15] I. M. Al-Joboury and E. H. Al-Hemiary, "Consensus algorithms based blockchain of things for distributed healthcare," *Iraqi Journal of Information and Communications Technology*, vol. 3, no. 4, pp. 33–46, 2020, doi: 10.31987/ijict.3.4.116.

[16] T. Shirabe, "Classification of spatial properties for spatial allocation modeling," *GeoInformatica*, vol. 9, no. 3, pp. 269–287, 2005, doi: 10.1007/s10707-005-1285-1.

[17] N. Alsaedi and A. S. A. Jalal, "Big spatial data systems - a review," in *IICETA 2022 - 5th International Conference on Engineering Technology and its Applications*, 2022, pp. 147–152, doi: 10.1109/IICETA54559.2022.9888481.

[18] H. Y. Kim and J. M. Kim, "A load balancing scheme based on deep-learning in IoT," *Cluster Computing*, vol. 20, no. 1, pp. 873–878, 2017, doi: 10.1007/s10586-016-0667-5.

[19] U. K. Jena, P. K. Das, and M. R. Kabat, "Hybridization of meta-heuristic algorithm for load balancing in cloud computing environment," *Journal of King Saud University Computer and Information Sciences*, vol. 34, pp. 2332–2342, 2022, doi: 10.1016/j.jksuci.2020.01.012.

[20] B. S. Roh, M. H. Han, J. H. Ham, and K. I. Kim, "Q-LBR: Q-learning based load balancing routing for UAV-assisted VANET," *Sensors (Switzerland)*, vol. 20, no. 19, pp. 1–17, 2020, doi: 10.3390/s20195685.

[21] V. Tosounidis, G. Pavlidis, and I. Sakellariou, "Deep Q-learning for load balancing traffic in SDN networks," in *11th Hellenic Conference on Artificial Intelligence*, 2020, pp. 135–143, doi: 10.1145/3411408.3411423.

[22] C. Singhal and K. Rahul, "LB-UAVnet: load balancing algorithm for UAV based network using SDN," in *2019 22nd International Symposium on Wireless Personal Multimedia Communications (WPMC)*, 2019, pp. 1–5, doi: 10.1109/WPMC48795.2019.9096139.

[23] Z. Luan, H. Jia, P. Wang, R. Jia, and B. Chen, "Joint UAVs' load balancing and UEs' data rate fairness optimization by diffusion UAV deployment algorithm in Multi-UAV networks," *Entropy*, vol. 23, no. 11, p. 1470, 2021, doi: 10.3390/e23111470.

[24] H. Guo, X. Zhou, Y. Wang, and J. Liu, "Achieve load balancing in multi-UAV edge computing IoT networks: a dynamic entry and exit mechanism," *IEEE Internet of Things Journal*, vol. 9, no. 19, pp. 18725–18736, 2022, doi: 10.1109/JIOT.2022.3161703.

[25] J. Jiang and G. Han, "Routing protocols for unmanned aerial vehicles," *IEEE Communications Magazine*, vol. 56, no. 1, pp. 58–63, 2018, doi: 10.1109/MCOM.2017.1700326.

[26] M. Ghamari, P. Rangel, M. Mehrubeoglu, G. Tewolde, and R. S. Sherratt, "Unmanned aerial vehicle communications for civil applications: a review," *IEEE Access*, vol. 10, 2022, doi: 10.1109/ACCESS.2022.3208571.

[27] I. M. Al Jawarneh, P. Bellavista, A. Corradi, L. Foschini, and R. Montanari, "Big spatial data management for the internet of things: a survey," *Journal of Network and Systems Management*, vol. 28, no. 4, pp. 990–1035, 2020, doi: 10.1007/s10922-020-09549-6.

[28] K. A. Eldrandaly, M. Abdel-Basset, and L. A. Shawky, "Internet of spatial things: a new reference model with insight analysis," *IEEE Access*, vol. 7, pp. 19653–19669, 2019, doi: 10.1109/ACCESS.2019.2897012.

[29] H. Gupta, A. V. Dastjerdi, S. K. Ghosh, and R. Buyya, "iFogSim: A toolkit for modeling and simulation of resource management techniques in the internet of things, edge and fog computing environments," *Software - Practice and Experience*, vol. 47, no. 9, pp. 1275–1296, 2017, doi: 10.1002/spe.2509.

[30] R. Mahmud, S. Pallewatta, M. Goudarzi, and R. Buyya, "iFogSim2: An extended iFogSim simulator for mobility, clustering, and microservice management in edge and fog computing environments," *Journal of Systems and Software*, vol. 190, p. 111351, 2022, doi: 10.1016/j.jss.2022.111351.

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