

ENERGY AWARE SMART CAR PARKING SYSTEM BASED INTERNET OF SPATIAL THINGS

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Abstract- With the advent of smart and green cities, the development of energy-efficient smart parking systems has attracted researchers to reduce environmental pollution in smart cities due to reducing traffic congestion as well as waste of time and fuel consumption. This article investigates how to integrate the Internet of Spatial Things (IoST) with workload balancing and image processing in fog computing to build an energy-efficient smart parking system. The suggested system applies Q-Learning, a reinforcement learning method, to achieve workload balancing and then deploys image processing to detect vacant parking slots. The proposed method's main objective of load balancing is to reduce energy consumption. The evaluation of the proposed system is done by comparing two case studies, fog-based and cloud-based IoST implementations, in the iFogSim simulator for various scenarios and scales. Moreover, it evaluates and compares the energy consumption of various devices. Experimental findings show that the devised system in fog-based IoST greatly reduces energy consumption with improves parking space availability in smart parking in contrast to the cloud-based deployment of smart car parking.

keywords: Smart parking, Internet of spatial things, Q-learning, Fog based IoST, Cloud based IoST

I. INTRODUCTION

Nowadays, the smart city emerged as a global trend that aims to improve the quality of life of the citizens [1]. It combines many smart sectors, such as smart energy saving mechanisms, smart security, and smart transportation [2]. Furthermore, numerous services associated with energy, environment, and healthcare are developed as part of the smart city concept and it regularly offers new services to all residents [3]. However, smart city confronts many challenges to sustainable mobility owing to the inadequate capacity of the city's traffic, transportation, and parking systems, along with the growing demand for parking spaces [4]. The deployment of energy-efficient automated parking systems is a bottleneck for smart cities. The IoT brings light to this challenge as it is utilized to reduce parking congestion and traffic [5]. It encompasses various things, devices, connected via the internet and has networking capabilities [6]. Despite it is expected for IoT to connect billions of devices, it can track things and vehicles from source to destination in real time via various technologies such as sensors and RFID [2][7].

Generally, IoT can be classified based on the characteristics of connected things and messages that are transmitted within the network. For instance, the Internet of Spatial Things (IOST) is an integrated framework consisting of attached smart devices that collect spatial data of objects for essential objectives. It has typical applications such as smart cities and smart transportation [8]. Moreover, the IoST generates huge amounts of data over time. Hence, the load balancing algorithm is an essential aspect of IoST's development [9]. The term "spatial data" refers to information about actual physical objects on Earth that is displayed on a map in the form of geographic coordinates [10]. IoST typically consists of four main layers.

Layer-1 is a target object or environment intended to exploit its spatial features. The sources of the required spatial data are the second layer, spatial Things. The third layer is fog/edge computing, which is a real-time, distributed intelligence system that responds to accelerated spatial processing. The data is then sent to be stored, processed, or visualized at layer four. To facilitate smart car parking, advanced storage and processing units are necessary. Yet for handling a large amount of data, the cloud-based setup is not efficient in terms of latency and energy consumption due to the centralized structure. Edge/fog computing has been suggested as a solution to this issue [11]. To address the new issues and the quickly changing IoT, the concept of fog computing (FC) was created. The primary goal of FC is to effectively deliver traditional cloud computing (CC) services close to things [7]. The research community works on energy awareness protocols and systems to improve transportation and implement smart and green cities [12]. To cope with the mentioned obstacles, especially the energy consumption by IoT, the study suggests an energy-aware smart parking system based IoST in smart cities. As the smart system in hierarchical architecture can help to save energy [2]. It develops a three-layered IoST framework based on FC. The first layer (L1) indicates the sources of spatial data. Processing of the parking space images is done using IoST fog computing in the middle layer (L2). The cloud layer is represented by the third layer (L3). The information regarding available parking spaces is displayed on the LED display of each parking area. The main contributions of this study are:

- 1) Design a smart parking system in a three-layered Internet of Smart Things (IoST) framework based on fog computing.
- 2) IoST network workload balancing is accomplished by using Q-learning (off-policy) and then deploying image processing techniques on the collected data to identify available parking spaces at Layer 2 (L2).
- 3) Evaluate the energy effectiveness and efficiency of a smart parking system employing fog-based IoST deployment in comparison to the cloud-based IoST through iFogSim simulation.

The remaining of this paper is structured as follows: Section II overviews the smart parking systems. The proposed approach with its architecture, algorithm that describes how it works, and experimental setup used to carry out the suggested methodology are described in Section III. The results are discussed in Section IV. Finally, Section V concludes the work and addresses future research directions.

II. RELATED WORKS

This section covers studies relating to smart parking. Authors design parking systems to locate empty parking slots using different schemes. For instance authors in [4] developed a novel parking system by utilizing machine learning, IoT, and smart city in real time. However, it is ignored parking management structures. while authors in [13] design online system access using a website. A system-integrated ultrasonic sensor served as the detector which sent data to the microcontroller for data logging purposes on the UBIDOTS cloud server. However, drivers must have reliable connectivity to the internet. Additionally using IoT, authors in [14] device smart parking system to detect empty parking spaces by image processing at the fog layer. However, storing the parking images in the cloud layer may result in privacy concerns for vehicle owners. Authors in [15] suggest an automatic car parking system in IoT architecture utilizing FPGA based on the driver's emergency condition. However, the robustness of the system may increase by using cameras to add facial detection to the system.

The literature review reveals that there have been tremendous efforts made to develop parking systems using Qlearning due to their ability to adapt to changing circumstances and work in a variety of scenarios. Q-learning is a reinforcement

learning (RL) algorithm in the field of machine learning that enables the agent to learn in the environment and perform an action by state transition to receive a reward or penalty based on the environment's feedback. The primary objective of the agent is to use the control strategy to select the appropriate action from a set of possible actions from a given state to a destination via the state transition procedure. When processing is enriched through repetitive stages, the problem is a Markov Decision Process (MDP) with unknown transition probabilities [16]. Moreover, Q-learning is a popular method for solving shortest path (STP) problems. It can determine the optimal path in the absence of prior knowledge of the environment. The ideal path is determined by looking at the state with the highest Q-value, which is updated continually [17][18]. Authors in [19][20] used Q-learning to develop an automated parking system. Moreover, it is utilized to develop a parking guidance system in an IoT environment as in [21]. Authors in [1] develop a parking system that is used to recommend parking areas to drivers using Amazon Web Services (AWS) in IoT based cloud computing. However, due to centralized control cloud based IoT, systems based on cloud computing suffer from latency and network usage [14] and energy as a result.

III. METHOD / EXPERIMENTAL WORK

A. *Proposed System Architecture*

This section illustrates the architecture that is proposed for a reference fog based IoST model. For simplicity, a three-layer IoST platform is taken into consideration as depicted in Fig. 1. intelligent cameras, microcontrollers, and LED displays are present in L1. To capture images of the slots, intelligent cameras are positioned above the parking slots in their field of view (FOV). Fog nodes are placed in (L2) and connected to the cameras by microcontrollers and to the cloud layer (L3) by a proxy server. Smart LED displays show the status of the parking lanes at the entrance of the parking sites. The suggested method is applied at (L2).

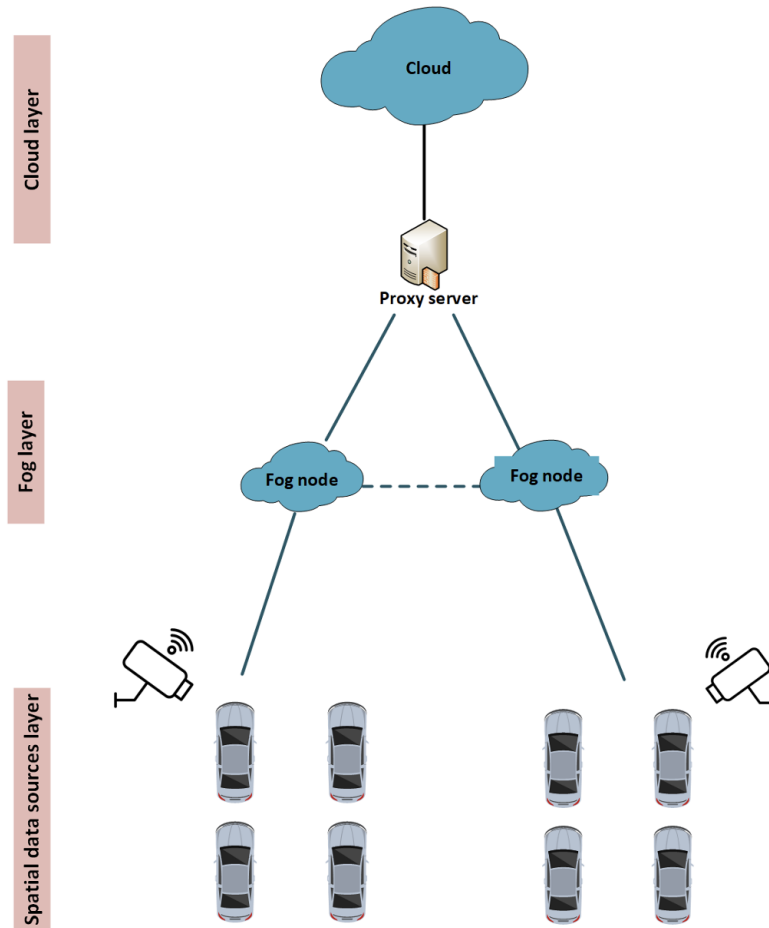


Figure 1: Smart parking architecture of three layers fog based IoST

B. Implementation of Proposed Method

A network of cameras is installed to convey their FoV. Firstly, cameras capture parking slot images and then send them to (L2) for processing every five seconds. The data sent from L1 to (L2) comprised spatial information. At (L2), Reinforcement Learning, Q-Learning, utilizes to balance the workload in fogs. For implementing Q-learning algorithm, consider that there is a set of environmental states $S = \{s_1, s_2, \dots, s_n\}$, and that each state has a set of actions $A = \{a_1, a_2, \dots, a_m\}$. An agent chooses an action $a_t \in A$ at time t in the state $s_t \in S$ to proceed to the next state $s_{t+1} \in S$ via the transition process and acquire immediate rewards r_{t+1} from the environment. Selecting an action that maximizes the reward and produces the maximum Q-value of each state to achieve load balance in a fog. Image processing is applied to locate available parking spaces. Initially, image acquisition phase is conducted. Secondly, the acquired image is converted into image with RGB format in the image segmentation phase. Then noise is removed in the image enhancement phase. Finally, image detection by Extraction of image features. Detecting free parking space algorithm is presented in Algorithm 1.

Algorithm 1: Detecting Free Parking space

Input: Parking Space Images

Output: Parking Spaces Information

1. System initialization;
2. Place smart cameras stationary
3. Acquire images of the parking area.
4. At fog, for each execution sequence (every transmission time) do the following:
5. a) Implement RL with a Q-learning algorithm on the data to attain workload balance.
6. Input:
7. s_t : current state; a_t action performed in state s_t ;
8. r_{t+1} : received reinforcement signal after s_t execution;
9. s_{t+1} : next state;
10. Discount factor $\gamma \in [0, 1]$; Step size $\alpha \in (0,1]$;
11. Begin
12. Initialize $Q(s_t, a_t) = 0$;
13. While (Q is not converged) do
14. For each episode do
15. Initialize S ;
16. For each step of the episode:
17. Utilizing the policy derived from Q (eg., ϵ – greedy), select one of the available actions;
18. Update the $Q(s_t, a_t) \leftarrow (1 - \alpha) Q(s_t, a_t) + \alpha [r_t + \gamma \text{Max}_{a_{t+1}} Q(s_{t+1}, a_{t+1})]$;
19. Move the state to a new state;
20. End while
21. End
22. Return Q value;
23. b) Implement an image processing approach on the image data to identify an available parking space;
24. apply image segmentation phase;
25. apply image enhancement phase;
26. apply image detection phase;
27. Return result;

C. Experimental Setup

This section discusses the implementation of the proposed smart parking system based IoST using extended iFogSim simulator, iFogSim2, [22][23] that is capable of working across multiple infrastructure layers and facilitate the integration of real-world datasets. It included class named Data Parser acts as the interface for extending data from external sources to iFogSim2 components [23]. The study adopts spatial datasets which collected from Central Business District (CBD) regions of major cities in Australia, including Melbourne and Sydney.

The simulation tool enables the deployment of the system using cloud based and fog based IoST architectures. In cloud based IoST deployment approach, cameras capture parking images and transmit their spatial data to the cloud for processing every five seconds. all of the functions run in the cloud. Whereas in fog based IoST deployment, the functions run in the fog nodes at (L2). Each fog gathers data from cameras in their FoV to locate the free spaces. By applying image processing following the implementation of Q-learning to distribute the workload across the fog nodes. Through a wi-fi connection, the fog transmits the slot's status to the LED display at L1. On the opposite side, the fogs use the proxy server for cloud connectivity. Since the fact that the smart cameras have Wi-Fi capabilities and are connected via a microcontroller, the

cameras simulated as sensors. Figs. 2 and 3 show an illustration of a fog based IoST architecture and a cloud-based architecture, respectively.

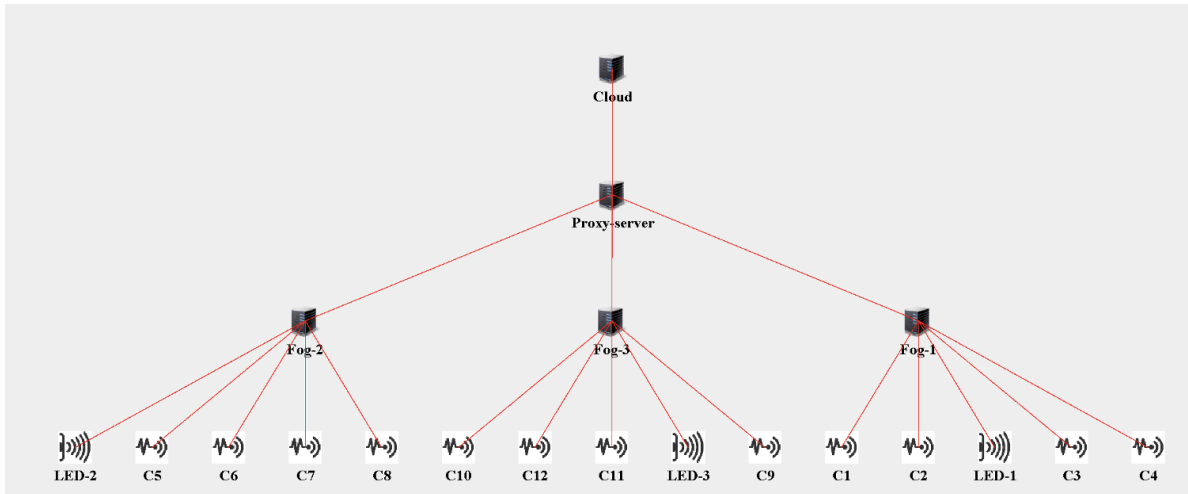


Figure 2: iFogSim topology of fog based deployment scheme

The proposed fog based IoST deployment study deployed on 12 scenarios to evaluate the performance. The physical architecture consists of a one cloud, one proxy server, and one to twelve fog nodes, each with four cameras and an LED display. For instance, Fig. 2 depicted the scenario of fog based IoST deployment, iFogSim topology of 12 cameras connected to 3 fog nodes then connected to the cloud server via the proxy server. Table I lists the fog based IoST infrastructure's specification parameters.

TABLE I
 PARAMETERS CONSIDERED FOR FOG BASED IOST DEPLOYMENT MODEL

Parameters	Cloud	Proxy	Fog
RAM (MB)	40000	4000	4000
CPU length (MIPS)	44800	2800	2800
RatePerMIPS	0.01	0.0	0.0
Uplink bandwidth (MB)	100	10000	1000
Downlink bandwidth (MB)	10000	10000	10000
Idle power (Watt)	16 * 83.25	83.4333	83.4333
Busy power (Watt)	16 * 103	107.339	107.339

Where MIPS (Million Instructions Per Second), RAM (main memory), level (hierarchy level of the device), rate Per MIPS (cost rate per MIPS used), busy Power (node power consumption in a busy state), and idle Power (node power consumption in an idle state).

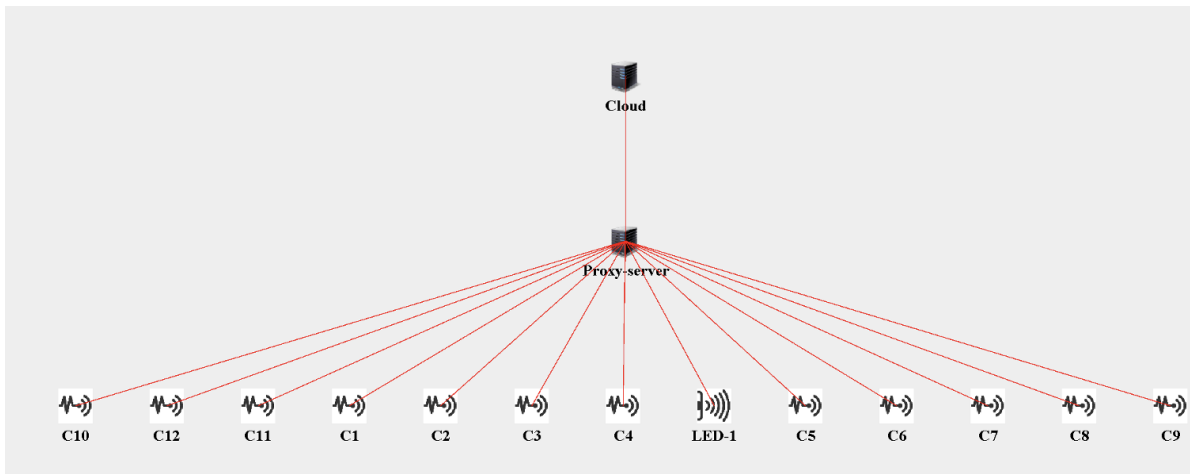


Figure 3: iFogSim topology of cloud based IoST deployment scheme

To assess performance in a cloud based IoST deployment architecture, the proposed study simulated two layers IoST. Through a router, one LED display and various cameras are connected to a cloud. Parking space images are uploaded by cameras to a cloud server to process and then updated the LED display with the status of the parking spaces. Fig. 3 depicted the scenario of cloud based IoST deployment, iFogSim topology of 12 cameras attached to the cloud server through the proxy server. Table II lists the cloud based IoST infrastructure's specification parameters.

TABLE II
 PARAMETERS CONSIDERED FOR FOG BASED IOST DEPLOYMENT MODEL

Parameters	Cloud	Proxy
RAM (MB)	40000	4000
CPU length (MIPS)	44800	2800
RatePerMIPS	0.01	0.0
Uplink bandwidth (MB)	100	10000
Downlink bandwidth (MB)	10000	10000
Idle power (Watt)	16 * 83.25	83.4333
Busy power (Watt)	16 * 103	107.339

IV. RESULTS AND DISCUSSION

This section assesses the effectiveness of the proposed smart parking system based IoST. As depicted in Sections I and II, integrating Internet of Spatial Things (IOST) with workload balancing in fog computing to reduce energy consumption in smart parking systems. Compared to cloud-based smart car parking deployments, the developed fog based IoST system significantly reduces energy consumption and enhances parking space availability in smart parking. The results depict that the energy consumption of smart car parking in fog based IoST is lower than cloud based IoST with different scenarios and scales as illustrated in Fig. 4.

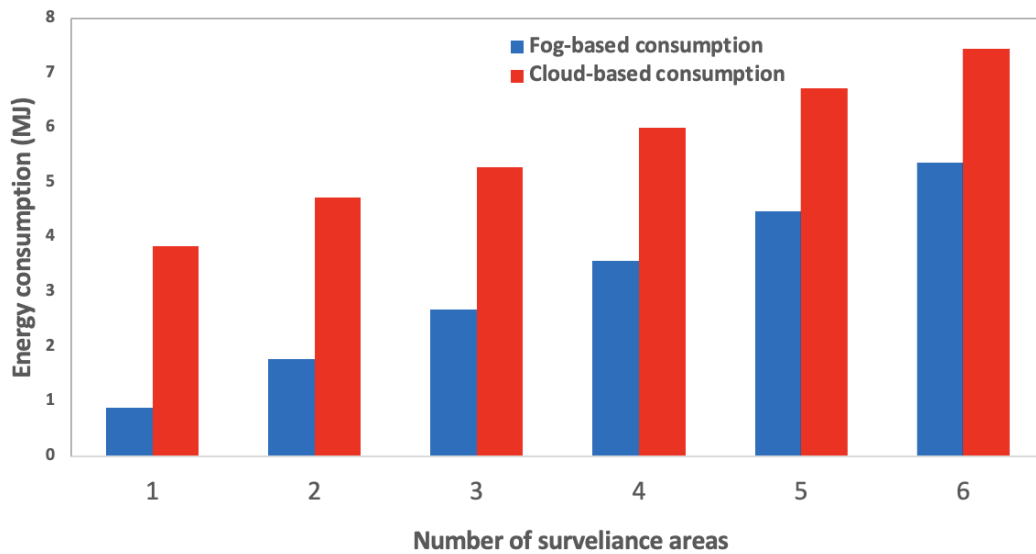


Figure 4: Energy consumption comparison between fog based and cloud based IoST.

To give an idea about the amount of energy consumed by different devices in the proposed network, Fig. 5 depicts the amount of energy consumed by various devices when deploy the proposed scheme in a scenario consisting of one cloud, one proxy, one fog covers parking area with four cameras deployed in fog based IoST.

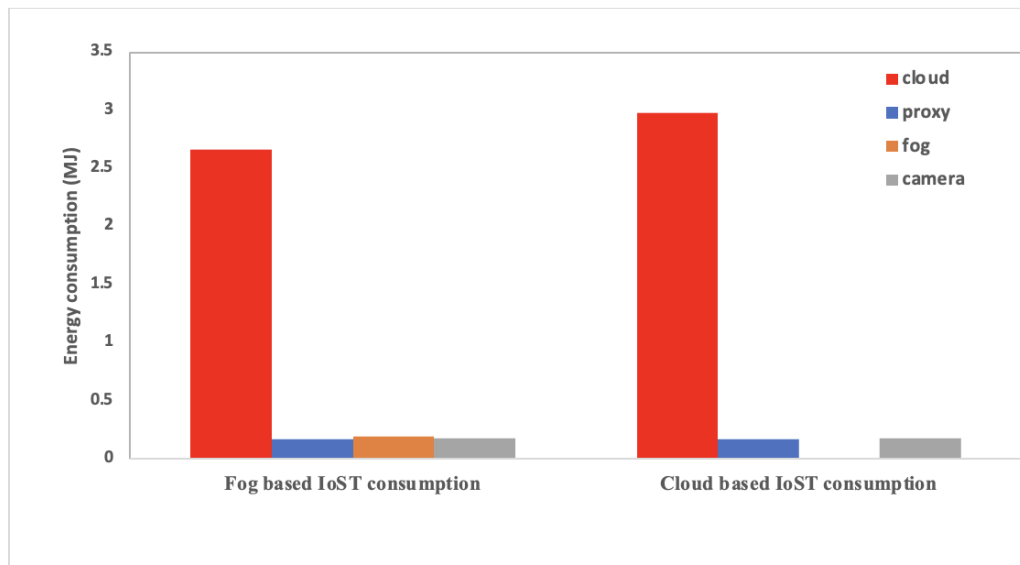


Figure 5: Energy distribution comparison between fog based and cloud based IoST.

V. CONCLUSION

Implementing an efficient smart parking system is a crucial component of the city management system for smart cities. Thus, the primary objective of the proposed study is to create a smart parking system based IoST. It deploys Q-learning algorithm and image processing techniques in fog based IoST deployment to locate vacant parking slots. Moreover, this architecture avoids system malfunction in the centralized cloud based IoST due to any failure. The iFogSim2 simulator was used to validate the suggested system with two configurations: fog and cloud based IoST. The result reveals the energy effectiveness of the invented scheme in the fog based IoST architecture for different scenarios and scales. There is a need to use encryption technologies in the future to give stored data more privacy. Moreover, it is also important to hold some comparison between the proposed work and others works. Additionally, the suggested system needs to incorporate Geographic Information System (GIS) tools.

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CONFLICTS OF INTEREST

The author declares no conflict of interest.

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