A Real-Time Cloud-Based Intelligent Car Parking System for Smart Cities

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***Abstract*—Nowadays, parking space shortages and traffic congestion are two issues that all drivers are facing in large cities around the world. Due to the growing number of vehicles and the mismanagement of available parking spaces, heavy traffic in crowded cities are severe. Therefore, there is a compelling urge for an intelligent and efficient car parking system which can be used for managing the limited parking spaces, thereby saving on time, cost, and fuel. In this paper, a secure and reliable cloud-based intelligent car parking system based on Internet-of-Things (IoT) technology for smart cities is presented. Integrated on-site data collection using wireless sensors along with real-time and streaming data analytics on data from IoT are investigated to dynamically check the availability of parking spaces in different parking areas and address the above-mentioned challenges.**

Keywords-Data Encryption Standard (DES) Algorithm; Intelligent Car Parking System; Internet-of-Things (IoT); Wireless Sensors.

I. INTRODUCTION

The increasing number of vehicles on the streets is a consequent problem in the population and global industrial growth [1-2] and has led to a shortage of parking spaces. Finding a parking space is a time-consuming process, which not only can reduce the economic activities' efficiency but also has a direct impact on social interaction and costs. Moreover, the inability of the network companies to provide updated information of the parking spaces and facilities, along with the excess space which big cars need for parking, are the reasons to establish a smart system for finding the parking vacancies [3-5].

Based on various technologies, a large number of smart car parking systems based on Radio Frequency Identification (RFID), Wireless Sensor Networks (WSNs), Wi-Fi, Bluetooth, ZigBee, agent-based technologies, and image processing techniques have been proposed in recent years [6-7]. Also, both the sensor node and WSNs have been used to develop different smart parking systems [6-8]. In systems, where there is the installment of a low-cost sensor node, the design considerations are based on the detection and monitoring of the status of each parking lot within some areas. Data can be collected via WSNs gateway installed at the parking areas to periodically report the statuses of different parking lots. The auto-toll, security management, etc., are also provided along with monitoring the parking areas. For the large parking areas, Vehicular Ad Hoc Network (VANET)-based smart car parking systems provide three important services to drivers, namely intelligent anti-theft protection, real-time parking navigation, and dissemination of the parking information [9-10]. Moreover, a location-centric IoT cloud-based parking violation management system helps the personnel in locating the cars which are parked improperly. Measuring and presenting the minimum cost route to the personnel to reach those cars helps in cutting the cost involved in commuting and detecting the average period of the parking violation.

Furthermore, there are automated energy-efficient vehicle parking systems which allocate some free of charge parking spots nearby to the entrance of the car parking area. These systems save the drivers' time to find a parking spot and utilize the parking spaces properly, while some systems save energy by turning on the lights only when the cars are in motion in the parking area. Saving searching time and lowering cost for drivers, some buildings attempt to guarantee parking reservations along with utilizing the efficient resources for managers of the parking areas at the same time [8-10].

The WSNs and IoT are the two efficient methods to achieve smart packing system in smart cities. The concept of IoT started with identity communication devices. IoT extends the use of the Internet through the communication infrastructures, and thus the internet connectivity of the devices and physical objects. The IoT is a system that enables different devices, such as mechanical and digital machines, computing devices, and objects to communicate and interact with each other through the Internet over a network without the need of Human-to-Human (H2H) and Human-to-Computer (H2C) interactions. In other words, the IoT provides a vision where different objects become smart and behave alive through various interactions, such as sensing, computing, and communicating by embedded small-scale devices which are in communication with remote objects or persons. In this regard, the cloud is a perfect partner for the IoT as it can be operated as a platform where all the data acquired by the sensors can be monitored and controlled from a remote location. The WSNs are used by the smart parking management systems to provide various functions, such as reservation of the parking lots, remote monitoring of parking areas, and automated guidance to the parking spaces, etc. Apart from this, different functionalities, e.g., payment facilities, improper parking detection, vacant parking space detection, available parking spaces monitoring, are provided by the ultrasonic sensor nodes-based smart parking systems [9-10].

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This paper proposes a secure, fast, and reliable cloud-based intelligent car parking system based on IoT technology, consisting of the Wi-Fi Access Points (APs), namely local parking management server, that a central server with the integration of Wi-Fi APs installed in the parking area provides the real-time information of each parking lot throughout the city and receives parking lot reservation requests from the car-users for the smart cities. The proposed intelligent car parking system considers each parking space as an IoT network and provides an overall optimal solution in finding available parking space, thereby saving on time, cost, and fuel.

The rest of this paper is structured as follows. Section II describes the proposed architecture, including the system overview, system architecture, and network architecture. Section III presents the system implementation and results. Finally, the conclusions are presented in Section IV.

II. Proposed Architecture

A. System Overview

The proposed system uses WSNs to monitor each parking space. The real-time status of each parking space is transferred to an integrated server through the wireless router. By using a wireless router, a large-scale parking area can be monitored at low cost. The car-users can choose suitable parking spaces by logging into the system. Information on the selected parking spaces should be confirmed to the drivers via different notifications. Based on the received feedback, the system updates the statuses of the selected parking locations to "pending" and prevents multiple reservations by the other drivers. If a driver does not attempt to pay the parking fees, after the pre-defined pending time (two minutes), the system determines that no car is parked at that spot, the system changes the status of the parking spot to "available". The system updates the statuses of all the parking spaces from the WSN nodes when new cars enter the parking area. Hence, the statuses of parking spots update in the real-time. Reliable operation and work in case of power shortage (working in the offline mode) can be guaranteed by using a battery bank which can supply enough power to the proposed intelligent car parking system [1-2, 11].

B. System Architecture

Figure 1 shows the proposed intelligent car parking system. All the information provided by the local parking management server at each parking area is stored in an integrated cloud platform. Therefore, the car-users can have direct access to the cloud server (not the local server) and search for the information of all the parking spots. The local parking management server consists of a controlling unit which is connected to all the Wi-Fi APs. Each AP has a particular tag and is used for checking the availability of the corresponding parking space. Along with the hardware configuration, an application software system is considered for the car-users to reserve the parking spaces and have access to the cloud server via 3G/4G mobile networks.

C. Network Architecture

The network architecture is shown in Figure 1, where the dashed lines represent the wireless links. This type of parking network includes wireless routers and forms an infrastructure for the connected car-users. The car parking network infrastructure allows the wireless sensors to connect to the router, which is a self-configuring and self-healing link network. The router can be connected to the Internet by the gateway functionality that can enable the integration of the car parking networks with the existing WSNs through the gateway/bridge functionalities in all the routers.

Each parking space represents a node in the car parking network and has a neighbor table to store the information of the current status of the car parking network. This information is used as a list to control the number of cars and also to prevent overloading at a specific car parking space. Also, by using the information of the neighbor table, the performance of finding free parking spaces increases. Figure 2 shows the proposed method to update the status of the car parking.

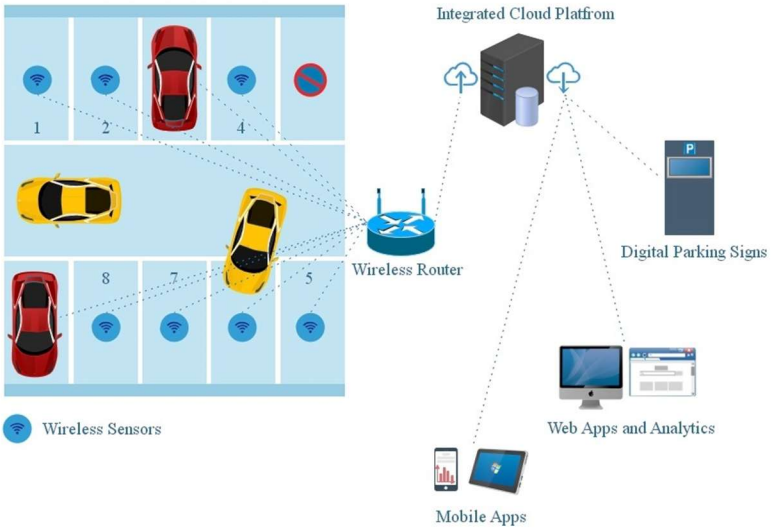

Figure 1. The architecture of the proposed intelligent car parking system.

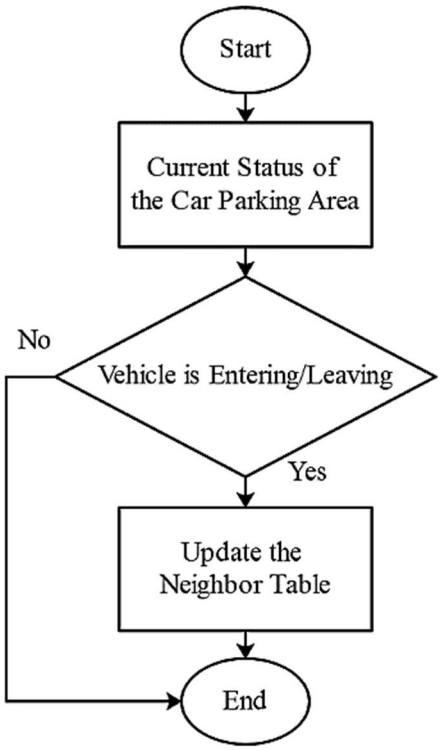

Figure 2. The proposed method to update the status of the car parking.

III. System Implementation and Results

All the car-users should log in to the system to find a parking lot. After authentication and successful login, the car-users can submit their requests for the parking spaces by using their smartphones. The response from the system includes the parking location and the fastest direction to reach it based on the current location of the car. Then, the car-users can reserve the parking space for two minutes and attempt to pay the parking fees. Failure to pay the parking fees leads to making the parking space available to the other drivers to choose/reserve. If the selected car parking is not available, the driver can report this matter to the server and the system searches to find a new parking spot. Figure 3 shows the flowchart of the system operations.

Finding the best parking space is a function of the request time and the distance between the vehicle and the parking space. This problem can be formulated as a single objective optimization problem, which the objective function is to find the best location, and the constraints are the availability of the parking space, vehicle arrival and departure time, current location of the vehicle, time of submitting the parking request, attempting to pay the parking fee, and the reservation status. Also, the priority of reserving the parking space is based on the request time. Considering two requests for a car parking at the same time, the system checks the vehicles' locations and finds the best parking lots.

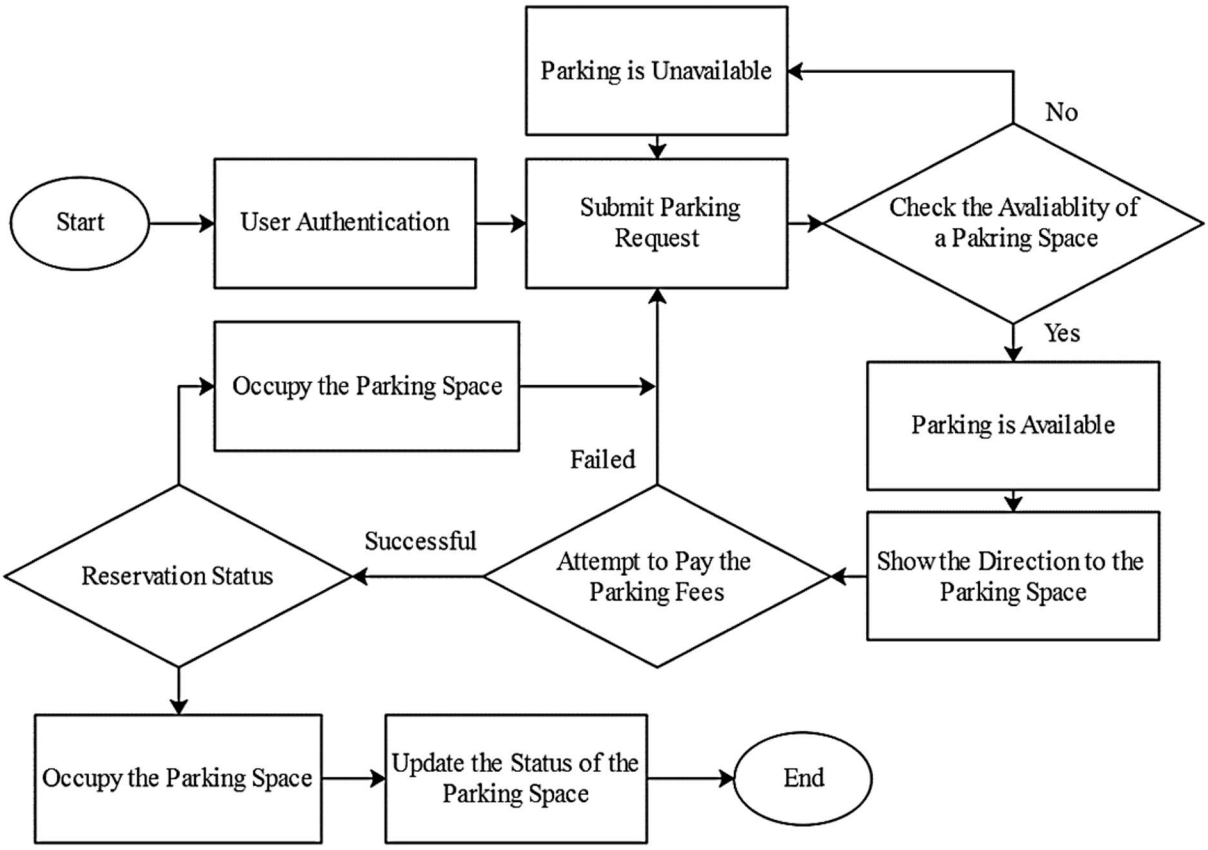

Figure 3. Flowchart of the system operations.

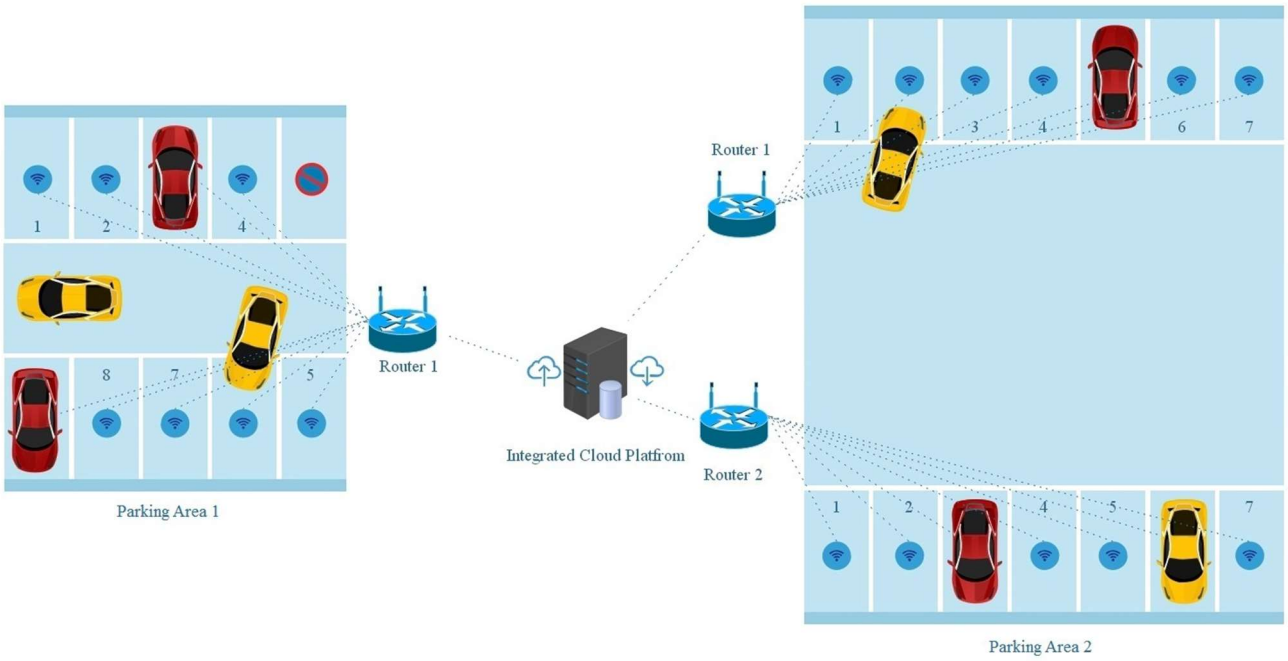

Figure 4. Architecture for the two-area parking network.

To check the performance of all the processes, a network deployment, including the car parking architecture, as shown in Figure 1, is simulated. The vehicles can randomly enter the car parking area and join the network. The simulation of the car parking is performed using four vehicles, in which one vehicle is leaving the parking area, two vehicles are already parked, and one vehicle is going to park. It is assumed that all the network nodes are interconnected, and the cars are parked properly. Figure 4 shows the results of the real-time monitoring system of the proposed intelligent car parking system for a single area parking network. The OPC[1], which is a client/server-based technology for data exchange between different devices, is used for specifying the communication of real-time data between the control devices from different nodes. In other words, an OPC server can make real-time data communication among different devices in a client/server-based network possible.

After running the software application, based on a specific Internet Protocol (IP), the operator can select the desired OPC server among the list of the available OPC servers. Each OPC server is connected to different channels. In each channel, different parking areas can be monitored. In each parking area, different routers are located, which are in communication with the wireless sensors. To increase the security of the system and prevent cyber-attacks, particular MAC addresses are assigned to the wireless sensors and routers. Therefore, an unwanted signal from an unknown source cannot be in communication with the router or the server. To ensure cloud computing security at a higher level, the data is encrypted based on the Data Encryption Standard (DES) algorithm. By choosing an individual channel, parking area, and router, the list of all the wireless sensors (which are under operation) can be observed. The operator can add the sensors to the monitoring list and read/check their current statuses. The system dynamically checks the status of each sensor, and data updates every 1000 msec.

It should be noted that by adding more routers and Wi-Fi APs, the vast possibilities encountered in the real-world and the scaling problems can be addressed. Besides, this possibility is taken into consideration that the cars can make a U-turn and the Wi-Fi APs send the wrong information to the server. To address this issue, the frequency of updating the status of each parking lot should increase.

More importantly, the car-users have this option to cancel their reservations for any reason, such as finding a better location, changing their decision to park in a particular parking area, etc. Therefore, the system should update the status of the parking space, and the car-users should submit their parking request again. However, by resubmitting the parking request, there are some unexpected human errors which can cause parking in the parking spaces that are supposed to be available. Issuing tickets to all the car-users and indicating that the car-users have violated the parking laws can be considered as an option to resolve this problem.

[1] Open Platform Communications

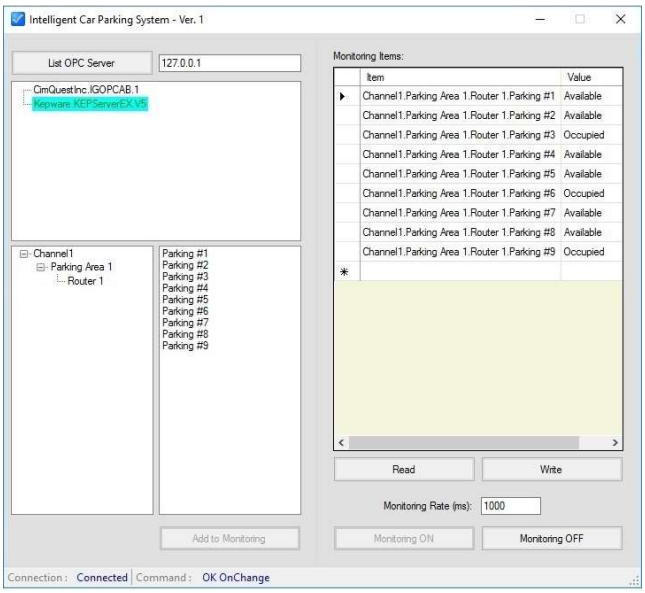

Figure 5. The real-time monitoring system of the intelligent car parking system for a single area parking network.

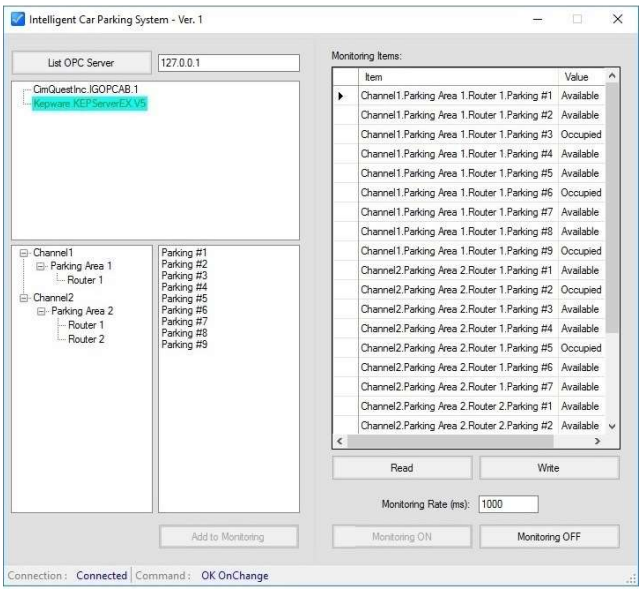

Figure 6. The real-time monitoring system of the intelligent car parking system for the two-area parking network.

To check the performance of the proposed intelligent car parking system, a new network architecture, as shown in figure 5, is considered. The new network consists of the two-area parking network with different routers and different parking spaces. Router 1 is connected to all the wireless sensors in parking area 1, while parking area 2 has two routers that are connected to two sets of sensors at different locations. After running the software application, the system quickly checks the network connection and shows the list of the available OPC servers, and the operator can choose the proper server for monitoring. Figure 6 illustrates the real-time monitoring system of the intelligent car parking system for more than one parking area. As there are two parking areas in the new network, the system shows two channels on the list, where channel 1 and channel 2 cover the car parking area 1 and 2, respectively. The system demonstrates the list of all the available wireless sensors (parking lots), and their list is transferred to the monitoring items panel. The monitoring system sorts the list of all the available wireless sensors based on their channel number, parking area number, router number, and parking space number. Meanwhile, the system can support a specific parking space of a particular channel, parking area, and router. The current status of the new network is monitored by selecting and reading the tags of all the available sensors, as shown in Figure 6.

Based on the availability of each parking lot and the location of each vehicle, the system suggests the closest parking space to the car-user for reservation and parking. Hence, it can enhance trip planning in crowded cities with less enforcement. Moreover, this system can propose the other alternative parking areas, if no parking spot is available in a specific parking location/area.

Compared with the existing car parking systems in [6], [10], and [12], the proposed intelligent car parking system in this paper is applicable for implementation in the real-world and performs faster with a higher level of security. In terms of system safety, the proposed system is designed in a timely and cost-effective manner and it can ensure correct execution. There is no limitation in terms of the number of interactions and by removing all the unnecessary items removed. from the design and programming parts, the proposed system is optimized. The proposed intelligent car parking system is designed for human-machine interface, ease of maintenance and modification or enhancement. The simulation results show that as long as the availability of each parking lot can be reported to the monitoring system, there is no limitation on the number of cars or sharing with other systems. The system can dynamically update the current statuses of the parking lots so that the occupancy of the parking lots by all the vehicles which do not use the provided cloud-based platform can be monitored.

IV. CONCLUSIONS

This paper proposes a real-time cloud-based intelligent car parking system based on Internet-of-Things (IoT) technology for smart cities to find the available parking spaces, thereby saving on time, cost, and fuel. The proposed system operates without image capturing and consequently, respects privacy rights. The simulation results demonstrate the performance, robustness, and effectiveness of the proposed system. To

ensure the security of the system and reduce the vulnerability of the system to the cyber-attacks, the system uses different MAC addresses for the wireless sensors and routers, which are located at different parking spaces, along with encrypting the data based on the Data Encryption Standard (DES) algorithm. The aggregated data is sent to the cloud for further analytics along with monitoring the statuses of the parking spaces and reporting the availability of the parking spaces for reservation and parking to the car-users.

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