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Internet of things and cloud based smart parking system design criteria

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Highlights

- IoT could be used for smart urban transport systems
- RFID, ZigBee and ultrasonic sensors are part of the key sensors
- Cloud-based IoT could be usable tool for parking systems

Abstract

In urban areas, traffic density is seen due to the congested residential areas and the high number of vehicles. The problem of drivers searching for parking spaces in central areas creates traffic. The Internet of Things (IoT) technology offers important solutions with its networking feature to solve problems such as traffic congestion, road safety and inefficient use of parking areas, which are waiting for solutions within the scope of Intelligent Transportation Systems. In this study, the technological infrastructures used by IoT-based smart parking systems are examined and integrated building models are proposed for system designs where parking lots are managed. For smart park design, devices, networks and cloud architecture used in IoT-based systems were examined and requirements were determined. The criteria of an application based on design central management are given. The criteria of an application based on design center management are given. Thanks to the smart parking system to be created in the light of these criteria, the closest parking area will be determined. These designed IoT-based systems will contribute to the reduction of traffic congestion, loss of time in full parking areas, air pollution caused by stop and start vehicles, and fuel savings in the economic field.

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1. Introduction

Intelligent transportation systems have been enriched with information and communication technologies as technology progresses. The Internet of Things (IoT) technology has emerged as a tool to increase the efficiency of city services by supporting smart cities in this context. Electronic devices in the digital world equipped with internet connection and sensor networks are interconnected with IoT technology [1,2]. Recently, many IoT-based smart city applications have been developed. Among these applications, there are many studies that overcome challenges such as smart transportation services, road safety, traffic management and vehicle parking [3-7].

Transportation has been one of the basic needs for humanity. The traffic congestion caused by the increasing number of vehicles over time has become an important urban problem by causing high energy consumption and air pollution [8]. Lack of parking spaces is one of the most important causes of traffic congestion. The relationship between congestion and parking arises from the fact that searching for parking spaces causes additional delays and amplifies local circulation. In the center of major cities, 10% of traffic congestion is caused by driving, and it has been found that drivers spend about 20 minutes searching for an empty parking [9].

Urban development faces significant challenges, particularly when it comes to limited parking spaces, and addressing sustainable urban mobility and reducing traffic congestion rank among the most crucial tasks [10]. Cities are becoming smarter through the implementation of data processing techniques, artificial intelligence algorithms, and the integration of various sensors [11-16]. One of the major concerns of today's smart cities is their inability to create adequate and well-managed parking lots to avoid traffic congestion in urban areas.

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Raj et al. [17] developed an IoT-based smart parking system for smart cities based on vehicle-to-vehicle communication and vehicle-to-infrastructure communication for autonomous vehicles. They propose a highly automated parking management system that is self-reliant in directing the driver to a nearby parking. The proposed smart parking system has created an electronic device that gathers the parking status information and helps drivers find and select the desired parking spot among the available parking spaces. One study designed a smart parking system that monitors parking spaces, which can be viewed on the website. The system uses MFRC522 for operations, ultrasonic sensor to detect parking spaces, a microcontroller sent to LCD via database to display parking space data on website [18]. Fahim et al. [19] compared a comprehensive technological approach in terms of sensors, network technologies, user interface, computational approaches and service provided in smart parking systems.

With a system design in which the data of IoT-based smart parking systems are transferred over the cloud, systems that inform the drivers in advance of the occupancy status of the parking lots in terms of location, day and time are developed. Canlı and Toklu, A novel mobile smart parking application, leveraging deep learning and cloud-based technology, has been developed to mitigate the issue of parking space search. Within the application, a predictive parking space service utilizing deep learning, specifically Long Short-Term Memory (LSTM), has been devised. Dynamic access to the previously created LSTM-based model is provided via the user's mobile device, and the occupancy rates of the parks are displayed on the mobile device by entering the relevant parameters [20]. Perkovic et al. conducted a study on the actual performance and power consumption of widely used sensor devices and Low Power Wide Area (LPWA) radio technologies (such as LoRa, Sigfox, and NB-IoT) presently accessible. They found that the lowest consumption was for LoRa devices utilizing the IoT system architechtures [21].

There have been many evaluation studies investigating applications, classifying parking systems, revealing smart parking sensors and technologies supported by IoT technology on smart parking systems [3, 22-28]. Similar sensors and communication protocols used in studies covering the application of IoT technology in different areas and current systems designed are shared in the literature [29-34].

According to the literature review given, instant data from the parking areas can be followed with various sensors. In addition, if an IoT-based structure is created, data can be transferred over a network. In this context, data is actively transferred to the cloud over the network connected to the technological infrastructure used in the parking areas, and a system that can be monitored remotely is designed and studies are carried out to provide solutions. In this study, current IoT-based technologies used in smart parking systems were investigated. Considering the differences in the technological infrastructure used in the parking areas, the criteria for integrating into cloud structures are given. Requirements and suggestions have been presented about the creation of designs that enable the control and monitoring of these systems by the center. It is clear that park management center designs, which provide solutions to traffic congestion in urban areas thanks to IoT technology, will become widespread with the arrangement of existing infrastructures in an integrated way.

2. Internet of Things

The term Internet of Things, coined by British technology pioneer Kevin Ashton, co-founder of the Auto-ID Center at the Massachusetts Institute of Technology in 1999, has become increasingly common [35]. This technology makes it possible to network everything around us and communicate with each other with less human intervention. IoT is defined as the connection of things in the physical world or an environment to a network with wired or wireless connections by connecting them with sensors or any embedded system. These connected devices are called smart devices or smart objects. And it consists of intelligent machines that communicate, interact with other machines, the environment, objects. Data can be processed using some processors such as network processor, hybrid processor MCU/MPU. Devices are connected using some technologies such as GPS, Wi-Fi, BT/BTLE, RFID [36]. Devices can be monitored and controlled using remote computers connected over the internet.

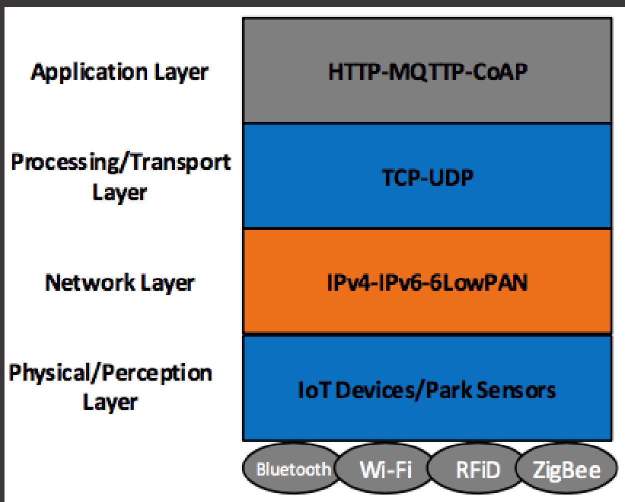

Figure 1. Sample figure and caption

An IoT architecture offers a comprehensive perspective on functionality and connectivity in an IoT ecosystem. Due to the constrained capabilities of IoT devices, authorization solutions specifically designed for IoT environments are frequently implemented in middleware. A four-layer IoT architecture model consisting of physical, network, middleware and application layers is given in Figure 1. The main functions of the layers are;

Application Layer: It is the top layer of the architectural stack that enables a participant to interact with the system. It encompasses Application Programming Interfaces (APIs) that facilitate communication with middleware, as well as user interfaces that enable end users to access services. Users can search and book their preferred parking spaces using a mobile app or web app. Likewise, parking service providers have the capability to transmit their parking-related information to the integrated system. As users engage directly with the integrated system, this layer delivers the ultimate service to end users.

The predominant protocol in the application layer is Hyper-Text Transfer Protocol (HTTP), which operates over Transmission Control Protocol (TCP) and User Datagram Protocol (UDP). Nonetheless, HTTP is known for its verbosity, complexity, and substantial parsing overhead. As a result, it may not be well-suited for resource-constrained devices in IoT systems. Consequently, several alternative application layer protocols have been devised [37].

The Constrained Application Protocol (CoAP) [38] stands out as one of the extensively adopted protocols for IoT devices, employing a client-server model and operating over UDP. It facilitates asynchronous message exchange and boasts minimal header overhead, simplifying message parsing [39]. Another prevalent application layer protocol is the Message Queue Telemetry Transport (MQTT), which operates above Transmission Control Protocol/Internet Protocol (TCP/IP) as a messaging protocol. MQTT is primarily employed for communication with remote locations where network bandwidth may be limited. However, due to its dependency on TCP, it may not be suitable for real-time processing applications. The Extensible Messaging and Presence Protocol (XMPP) [40] is another widely utilized application layer protocol in IoT. It is designed for streaming Extensible Markup Language (XML) elements and facilitating real-time exchange of structured data.

Middleware layer serves the purpose of facilitating connectivity and interoperability within the IoT ecosystem. It comprises intermediate nodes responsible for processing data received from lower layers and forwarding it to the application layer. The role of middleware in the IoT ecosystem often entails enabling connectivity, interoperability, storage, and data computation. Various types of middleware solutions have been proposed for IoT [41-42]. A comprehensive literature review of IoT reveals that many existing solutions are predominantly based on cloud computing and edge computing as middleware [43]. Cloud computing holds a central position in most IoT platforms, offering flexible and scalable data storage and processing capabilities. The role of the cloud in IoT architecture varies based on the specific application needs and requirements.

The network layer in an IoT ecosystem serves the purpose of facilitating network support and data transfer between nodes [44]. It is responsible for implementing communication protocols required for seamless data exchange. The prevalent network layer protocols utilized in IoT systems are IPv4 and IPv6. IPv6 mandates a minimum MTU (Maximum Transmission Unit) size of 1280 bytes, whereas the IEEE 802.15.4 link layer permits a maximum frame size of 127 bytes. Consequently, supplementary protocols are necessary to enable packet compression for transmitting IPv6 packets over IEEE 802.15.4.

The IPv6 over Low Power Wireless Personal Area Networks (6LoWPAN) [45] protocol is designed to operate on the Low-Rate WPAN specification. It utilizes encapsulation and header compression techniques to facilitate the transmission of IPv6 packets over IEEE 802.15.4 networks. This enables the establishment of a mapping between the link and network layers. The primary objective of 6LoWPAN is to provide IP support for low-power IoT devices. Additionally, Thread7 is another network layer protocol specifically tailored for device-to-device communication in building automation. It is based on IPv6 and 6LoWPAN, offering a comprehensive solution for building automation networks.

IoT systems further expand upon the architectures and protocols utilized in Wireless Sensor Networks (WSN) by incorporating web resources. WSN represents a specific type of IoT network architecture known as a Low-Power and Lossy Network (LLN). In LLN, both devices and routers possess constrained memory and processing capabilities. RPL [46] is an IPv6 routing protocol designed specifically for LLN, efficiently routing various types of traffic, including device-to-central point, central point-to-devices and inter-device communication.

The network layer facilitates communication between the integrated system and users, encompassing parking areas located at various points. It enables the transmission of data from users and parking centers to the integrated system. This layer incorporates diverse communication technologies, including LAN and WAN, for utilization by users, parking service providers, and IoT devices associated with the parking system (e.g., parking sensors and security cameras). It integrates multiple wireless communication technologies such as Lora, Bluetooth, Wi-Fi, along with existing GSM technologies like 4G and 5G. Additionally, this layer ensures scalability and handles the physical layer security of the system.

The physical layer of an IoT system serves to define the sensing and control capabilities. It comprises physical nodes, including sensors and actuators, which detect and interact with the environment based on changes or user commands [47]. These nodes generate resources that are subsequently transmitted to application nodes through the network and middleware layers. The physical layer encompasses a variety of IoT devices, forming a diverse combination [43].

In IoT ecosystems, different protocols are employed in the physical layer and data link layer, classified based on the type of network they support: Local Area Network (LAN), Personal Area Network (PAN), and Wide Area Network (WAN). Among the commonly used PAN protocols in IoT are Radio Frequency Identification (RFID), Bluetooth, ZigBee, and Z-Wave. RFID is extensively utilized in IoT environments for device identification purposes.

The IEEE 802.15.4 standard is specifically developed for low-speed wireless personal area networks (LRWPAN), providing cost-effective and low-power communication for devices in close proximity. Zigbee is a protocol that is built upon the LRWPAN concept, incorporating additional components for the network and application layers. Similarly, the Z-Wave protocol operates on low-frequency radio bandwidth and is proprietary, not based on a specific standard. Z-Wave encompasses the entire network stack, ranging from the physical layer to the application layer [48].

3. IoT and Cloud Based Smart Parking Systems

Many problems such as vehicle traffic congestion, road safety and ineffective utilization of parking spaces are solved by the IoT technology. When trying to reduce traffic congestion, IoT-based traffic control systems must evaluate all congestion-causing situations. Searching for a parking space can cause traffic congestion and increase Carbon Dioxide (CO_2). In order to find a safe and fast parking spot for drivers in traffic, identifying a parking spot close to its destination and making a reservation in advance has a great effect on reducing congestion.

With IoT-based smart parking systems, the information of empty parking spaces is obtained with the help of sensors and the closest parking location information is sent to the driver. Intelligent systems allow drivers to see their parking spaces and even make online reservations based on their remaining distance to the parking spaces. The needs and infrastructures of smart parking systems should be designed according to the requirements of IoT technology and should be developed in an integrated manner with new technologies. In this section, sensors, network and communication protocols, auxiliary communication technologies used in the infrastructure to be created with IoT technology for smart parking systems are given.

RFID is a communication technology that enables the identification of specific targets and the reading and writing of relevant data without the need for mechanical or optical contact. This is accomplished through the implementation of the RFID system, also referred to as electronic tags. It is also the largest and fastest developing identity technology widely applied to the IoT. RFID technology can be categorized into energized, de-energized, and semi-powered types. Energized RFID tags are equipped with their own battery, enabling them to have a long read and write distance. However, they tend to be larger in size and come with a higher cost. On the other hand, de-energized RFID tags do not have built-in batteries and rely on power provided by the reader emitter. These tags are smaller in size, more cost-effective, and boast a longer life cycle. They typically have a reading distance ranging from 10mm to 5m, making them widely utilized in applications such as public vehicle cards, food carts, and bank cards [49].

In addition to Wireless Sensor Networks (WSN), RFID is employed to maintain the driver's awareness of the closest parking spot available in the IoT environment. It can be specifically tailored software-driven to gather real-time data on the status of parking spaces. It provides many conveniences to the user, such as the possibility of paying the parking fee via e-wallet. RFID-based systems can easily support extensive parking applications such as parking lot reservation and false parking warning [50].

WSN technology consists of nodes that provide sensing and communication. WSN nodes are usually small and battery powered devices. It easily provides innovative services that facilitate drivers' work quickly and efficiently when searching for an empty parking space nearby in the city. The WSN network architecture can be established by deploying monitoring nodes within parking lots and routing nodes responsible for transmitting the data collected by the monitoring nodes to the base station, forming a tree-like topology. The communication between different sensors and the base station relies on ZigBee technology, enabling short-range communication and minimizing energy consumption [51]. Smart parking reservation applications using ZigBee technology and Bluetooth are being developed. ZigBee sensors are used to detect the vehicle, while Bluetooth communication technique is used to authenticate the driver and also to book a place by identifying free spaces. The Bluetooth range is limited, so if the driver is not active, the connection will be lost and a new slot must be reserved again [52].

ZigBee, renowned for its energy-efficient nature, can operate for extended periods using a single battery. This technology leverages the IEEE standard 802.15.4, offering an impressive outdoor range of 120m and an indoor range of 40m, surpassing the capabilities of Bluetooth and Wi-Fi. Within the smart parking model, each router node utilizes network topology to establish a connection with the main coordinator, enabling direct communication except for the end nodes. ZigBee technology stands out as a superior choice compared to Wi-Fi and Bluetooth due to its inherent self-orientation and self-healing capabilities. It excels in monitoring and controlling real-time applications, thereby facilitating drivers in locating nearby parking spots, reducing the incidence of accidents, and enhancing vehicle safety. The ZigBee device operates as a transceiver, enabling the acquisition of data from vehicle-detecting sensors and its transmission to the central base station, depending on its operational state [53].

The automatic detection of parking spots, utilizing visual-based methods, relies on the Area View Monitor (AVM) system. Within this system, the mall is strategically positioned to offer an expansive perspective of the parking lot for a single vehicle. The identification of parking spaces is achieved through the implementation of the Line Segment Detector (LSD). Moreover, the AVM employs image segmentation techniques and stereo vision algorithms to effectively identify and navigate around minor obstructions present near parking spaces [54].

The integration of the Fusion Sensor with the AVM and ultrasonic sensors enables the identification of vacant and occupied parking spaces. The process begins with the utilization of various AVM image sequences to detect the markings associated with the parking spaces. Subsequently, the occupancy status of the parking spaces is determined by employing ultrasonic sensors, resulting in the acquisition of relevant information.

The AMR Sensor utilizes Anisotropic Magneto Resistive (AMR) sensors that are deployed within parking slots located alongside the road. The detection of slots is classified as a binary pattern recognition challenge, distinguishing between two states: either occupied (full) or unoccupied (empty).

Ultrasonic Sensor is used together with IoT technology to detect empty and occupied parking spaces. Two ultrasonic sensors are used for each parking space. A specific threshold is established for each sensor to identify the presence of a vehicle within the designated parking space. The parking space is considered occupied only when both sensors detect the presence of a vehicle, thereby indicating its occupancy. These sensors work by emitting higher pitched sounds than the human ear can detect. These sound waves are reflected by nearby objects and send signals back to the sensors. The sensors determine and construct a suitable representation of the surrounding environment by assessing the duration of sound wave reflections from various points within the field.

The Magnetometer Sensor is a device that can seamlessly detect vacant parking lots by measuring the wireless magnetic field change. Parking lot with empty slots is easily detected, mostly using sensors such as magnetometer and accelerometer to minimize parking search time.

Infrared Sensor is an electronic device that emits light to detect any surrounding object. It detects motion and measures the temperature of the object. The presence and absence of the vehicle is detected by placing IR sensors to find the available parking space.

The accelerometer is among the cellular sensors via smartphones as an accelerometer embedded sensor. It helps to determine whether the driver inside the vehicle is moving the vehicle. At the same time, GPS and gyroscope sensors are used to detect empty parking spaces and create a heat map on the smartphone [25].

Transducer Sensor is a test device that can detect the tested information and convert the detected information into electronic information or other necessary forms.

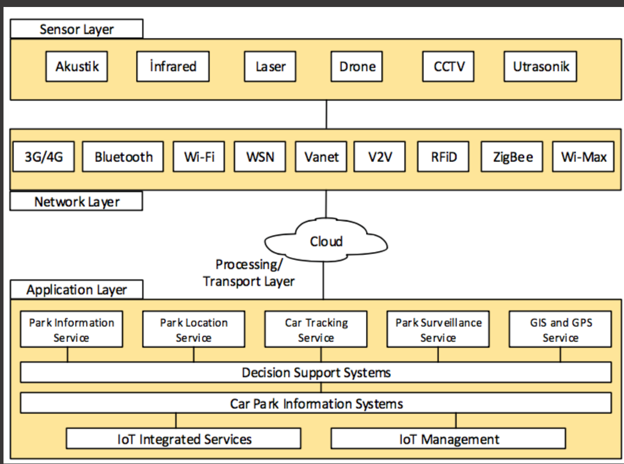

Figure 2. Smart parking system layer and components

In the examples of IoT-based smart parking systems, sensors detailed in this field are used as basic components, and a network is established by selecting the appropriate communication technologies for the system. In Figure 2, the components in the layers as a whole within the scope of the smart parking system are given. When objects are made accessible to the Internet with the designed systems, they can be supported by mobile applications and web applications, and operations such as data collection, data processing and data sharing can be easily provided over a cloud system.

3.1 Cloud design in smart parking systems

A cloud fabric is a model that offers universal, instant network access to a shared pool of customizable computing resources, thereby providing a synonym for a highly available and scalable infrastructure (networks, servers, storage, applications, and services). The Cloud's effectiveness as a model stems from its layered architecture and standardized service models, which are pivotal characteristics contributing to its success. Cloud computing services are offered as Software as a Service

(SaaS), Platform (Platform as a Service-PaaS) and Infrastructure (Infrastructure as a Service-IaaS) [55-56]. IaaS contributes to creating a scalable data center structure by creating infrastructure and virtual server as the basic and flexible cloud model provided by cloud computing technology.

Cloud architecture can be divided into four layers: data center (hardware), infrastructure, platform and application layers. Parking systems, which are considered an important component of ITS for smart cities, should be planned to include all layers. Within this system, it is possible to incorporate an embedded web server, a central web server, sensors, and mobile or web applications specifically developed for parking purposes. Especially in the application part, a parking service should be considered together with supporting cloud applications, web applications and mobile applications.

Based on the state of the parking systems, structures based on the distributed cloud architecture of IoT are being created to improve the process of finding the nearest parking lot in minimum time and to manage the parking systems. Users who have access to the cloud can monitor their reservation information, parking lot location, number, parking fee, distance to the parking lot and availability time as real-time data. In order to prevent the fuel and time spent searching for empty parking spaces, and to prevent traffic jams, a large network is established with the management of the car parks, which are designed as a smart parking system, from a central point.

Steps to be followed in Smart park design created in a cloud system: A designed Cloud-based Smart Parking system should be integrated in all directions. Sensors can be added to the system according to demands, as well as middleware and end-user software that serve the user, variable demands should be presented in a customizable structure for each parking area. With the establishment of an IoT management center, IoT integrated services are connected to the communication layer in the background with a common interface. These are parking lot finding, inspection and information services, GPS services, license plate reading, vehicle tracking services, etc. Common challenges include security, reliability, scale, heterogeneity. Enabling the provisioning of essential resources, storage, and computational power in a transparent and secure manner for vast volumes of diverse and personalized data originating from dispersed sources is accomplished through the advancement of diverse middleware platforms within a finely grained system. Middleware platforms are important so that different IoT ecosystems can communicate with each other.

Within the scope of smart parking systems, different detection technologies can be used in the first layer; laser, infrared, microwave radar, ultrasonic, acoustic sensors or vehicles with video image processing to detect the status of car parks, 3G/4G communication module installed for tracking cars, etc. is selected.

The processing unit acts as an intermediary between the sensors and the cloud. All sensors are wired/wirelessly connected to the processing unit. Data collected from various sensors is sent to the microprocessor, which we call the processing unit. It transmits this data to the server via various protocols over a channel.

In the communication layer, a connection is provided between the application and the sensor layer using various wireless technologies.

At the application layer, the mobile application acts as an interface for web application end users to interact with the system. The application must connect to the server by selecting a secure channel and authorization. The purpose of this developed application includes services such as providing information about the location and availability of parking spaces, and providing the shortest direction. Data transfer takes place between the server and the user application. Platform as a Service (PaaS), Software as a Service (SaaS), Infratructure as a Service (IaaS) services are selected based on different parking services information, processing and storage resources. The cloud acts as a database to store all records regarding parking spaces and end users who have access to the system. It keeps a record of each user connected to the system and can include information such as the time the vehicle was parked, the parking time, the amount paid by the user, and the payment method. It can be structured based on the adaptable essence of the cloud, which permits the system to incorporate an unrestricted count of users at any hour of the day.Continuous backups of data stored in the cloud should also be made so that data can be easily and quickly recovered in case of any system failure.

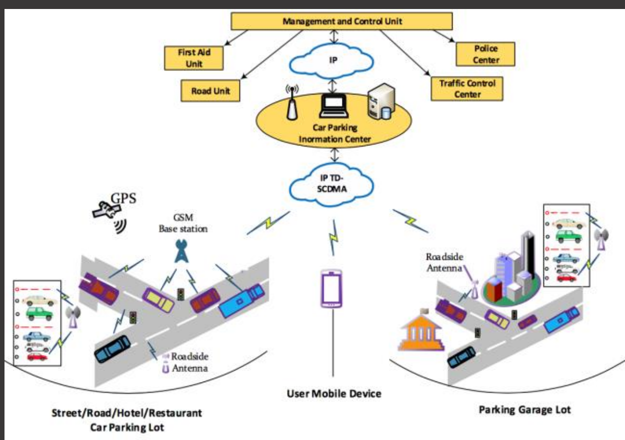

Figure 3. Cloud-based smart parking system and IoT supported smart city architecture

An example design of a smart parking system with centralized management is given in Figure 3. Cloud-based platforms help make it easier to develop and deliver IoT plugins that enable device to connect to the Cloud. While this service model hides the complexity and heterogeneity of the infrastructure, it also meets the complex requirements for the Cloud such as high activity, scalability, security, easy configurability and flexibility. If there is a demand for smart planning in a city consisting of car parks or indoor car parks in areas such as streets, roads, hotels, restaurants, sensor information is evaluated using multiple communication protocols, and a management system is established by transferring them to the common data center. The data coming to the management center of the system is transferred to the drivers in the fastest way via web or mobile applications.

When cloud-based IoT systems receive a request from the driver looking for the nearest parking spot, the system will process the driver's GPS coordinates and create an area around that location. The system will prepare the road planning that the driver will follow towards one of these parks depending on the traffic situation in this area and the total travel distance between the driver. To get the status of traffic in this area, the number of vehicles on a given route, services such as Road Side Unite (RSU) and Google Traffic can be used. By determining the traffic situation in a certain area, the most suitable route for the driver to reach the nearest parking lot will be created.

4. Conclusion

Smart parking systems and traffic management systems have become reality with the growth of Internet of Things and Cloud technologies. Insufficient parking spaces result in traffic congestion, imbalanced supply and demand, overcrowded parking areas, unfair pricing, on-road and off-road parking, aimless driving, environmental pollution, and deterioration. It has been determined that the presence or knowledge of parking information at the destination to improve the parking facilities of a city and increase the quality of life of the people provides an important solution to the traffic that will be caused by the delay of finding a parking place. Therefore, a parking space estimation system should be developed that can inform the drivers in advance of the occupancy status of the parking lots in terms of location, day and time. In this study, a system design in which the data of IoT-based smart parking systems are transferred over the cloud and the criteria for a system design that provides central management are presented. For smart parking design, devices, networks and cloud architecture used in IoT-based systems were examined and considering the differences in technological infrastructure used in parking areas, requirements and suggestions were given about the features of integration into cloud structures, the creation of designs that allow these systems to be controlled and monitored by the management center.

The cloud structure offers a scalable and flexible data center structure thanks to its configurable computing resources. Within the scope of this study, the technologies used in the creation of IoT and cloud systems are detailed and the necessary criteria for a smart parking system are presented in order to solve the heterogeneity of parking spaces established in different locations and with different technologies. It has been determined that the technological findings revealed as a result of the applications given in the literature review and all the researches are sufficient for the creation of integrated structures for the smart parking system. The recommendations given for the necessary hardware and software selections in an effective design are matched with the literature. Service is provided to users by selecting the most suitable protocols for IoT devices at the application layer. Services such as vehicle information, location, tracking services work in this area. Network and communication protocols and auxiliary communication technologies that provide the connection to the physical layer through the network layer are selected depending on the infrastructure. While using a large number of different sensor technologies created in parking areas as infrastructure, appropriate design suggestions were given to be integrated into the upper layers. Thus, thanks to these cloud-based structures, it contributes to ensuring the regular flow of vehicles in the city without traffic jams, preventing time loss in full parking areas, reducing air pollution caused by vehicles that stop and start, and saving fuel in the economic field.

Declaration of Interest Statement

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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