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SMART 2022 Editors

Lasse Berntzen, University of South-Eastern Norway, Norway

SMART 2022

Forward

The Eleventh International Conference on Smart Cities, Systems, Devices and Technologies (SMART 2022), held between June 26th and June 30th, 2022, continued a series of events covering tendencies towards future smart cities, specialized technologies and devices, environmental sensing, energy optimization, pollution control and socio-cultural aspects.

Digital societies take rapid developments toward smart environments. More and more social services are digitally available to citizens. The concept of 'smart cities' including all devices, services, technologies and applications associated with the concept sees a large adoption. Ubiquity and mobility added new dimensions to smart environments. Adoption of smartphones and digital finder maps and increasing budgets for technical support of services to citizens, settled a new behavioral paradigm of city inhabitants.

We take here the opportunity to warmly thank all the members of the SMART 2022 technical program committee, as well as all the reviewers. The creation of such a high-quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated much of their time and effort to contribute to SMART 2022. We truly believe that, thanks to all these efforts, the final conference program consisted of top-quality contributions. We also thank the members of the SMART 2022 organizing committee for their help in handling the logistics of this event.

We hope that SMART 2022 was a successful international forum for the exchange of ideas and results between academia and industry and for the promotion of progress in the field of Smart Cities, Systems, Devices and Technologies.

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***Abstract*—The rapid growth in number of passengers per household in major cities led to problems such as traffic congestion, increase in harmful emissions, and traffic safety concerns. Mismanagement of available parking spaces due to a lack of intelligent parking systems is acknowledged as one of hot topics in smart city concepts. In this paper, we present a small-scale study conducted on the premises of University of Oulu parking space to test a new real-time management of parking lot availability using Internet-of-Things (IoT) sensors and a mobile application.**

***Index Terms*—Smart Parking system, Internet of Things, Smart Cities, Intelligent Systems.**

I. Introduction

It is anticipated by the industry experts that there will be 2 billion automobiles in circulation by the year 2040 [1]. This creates a constant need to appropriate infrastructure that must be made accessible to support the growth in both the number of vehicles and the human population within a constrained area. Large urban areas with a high volume of pedestrians, such as shopping malls, entertainment centers, and airports, are prone to experiencing significant levels of traffic congestion. This may be the result of improper parking of vehicles or the absence of adequate parking management systems. As a result, the need for efficient optimal car parking management systems is crucial. Often inefficient car parking management results in increased fuel, traffic congestion, and environmental pollution [2].

Over the past few years, numerous studies have been carried out in the field of intelligent car parking systems. These studies were based on technologies such as Radio Frequency Identification (RFID), Wireless Sensor Networks (WSN), Bluetooth, Wi-Fi, ZigBee, and image processing. However, in Finland, numerous available mobile applications, namely, ParkMan [3], and EasyPark [4], are limited to only facilitating users with online parking tickets, without any ability to deliver on parking lot availability. This paper proposes a smart parking intelligent system based on IoT technologies, smart sensors, and a mobile application that provides the user with real-time parking information about the parking lot and available spaces. In addition, we also present some exploratory analyses based on the dataset collected from Feb 2021 to Nov 2021 at a pilot study conducted within the premises of the University of Oulu car parking area. The study was conducted as part of a European Regional Funding on Smart Parking in the Oulu region expects to create an economic, environmental, and societal impact as well as contribute toward policy modeling and evaluation.

The rest of the paper is structured as follows. In Section II, we present the related works. In Section III, we provide an overview of the architectural design of the proposed solution. In Section IV, we present the detail of the mobile application. In Section V, we present the small-scale study analysis. Finally, we conclude our work in Section VI.

II. Related Work

Managing public parking spaces under municipal mobility plans is a critical problem with significant economic repercussions. A study in [5] revealed that 30 percent of the congested traffic in the city is attributed to cars searching for parking spots [5]. Likewise, it is also proven that the limited availability of parking lots influences driver behavior, levels of carbon dioxide (CO_2) emissions, and traffic safety [6][7] as well as traffic density [8].

The demand for available parking lots is dynamic, meaning that this varies over time and space. There is a rational need to provide drivers with real-time information on the location and condition of available parking spaces [9]. With the large-scale field deployments since 1996, the quantity of information in this domain becomes extensive, especially with the development of smart city concepts, which raises the question of efficient use of such big data information. Lin et al. [10] undergo a comprehensive, though not systematic, review of smart parking solutions from 2000 to 2016, identifying certain challenges and unaddressed concerns. In [11], the authors

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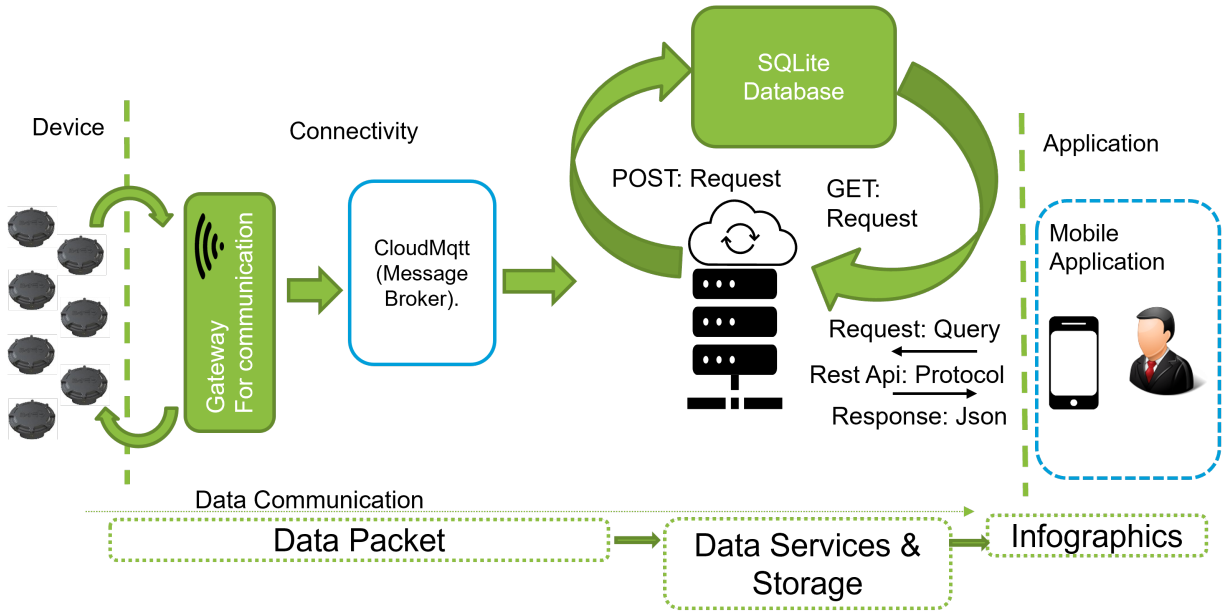

Figure 1. Overall Smart Parking System Representation.

suggested using ultrasonic sensors to monitor occupancy status and illegal parking in a multilevel parking lot. Light Emitting Diode LEDs were suggested to show the number of available parking spots, vehicle navigation, and parking lot conditions. In [12], the authors utilized photoelectric sensors in to identify cars in a controlled zone. The sensors were deployed at the parking lot's entrance and exit points and linked to the server for data processing and distribution. Such a setup may offer real-time information on the number of available parking spaces but not the precise location of the available spot. A microcontroller and an ultrasonic sensor network were proposed in [13] to determine the occupancy of automobiles in a parking lot. The drivers were given a mobile application to search for open lots or book slots with payment choices. If a mobile application is unavailable, the driver may view a monitor at the entryway. A disadvantage of this approach is the necessity of a human staff to process, validate, and allot the slot rather than an autonomous procedure. Using WSN's, the authors in [14] built a parking system that used a magnetometer as the sensing device to detect parking spots. WSN was used to guarantee that the data was wirelessly sent and routed to the base station, which was then used to measure conditions of interest such as magnetic (metal) fluctuations and light radiation (radiation or reflection of light from objects). Authors in [15] used a light sensor to identify the presence or absence of a vehicle by sensing the quantity of ambient light by communicating via the ZigBee protocol. Since this requires the use of additional sensors, this approach is unreliable when utilized for outdoor parking. The use of two distinct sensor networks - ultrasonic sensor for indoor parking lots and magnetic sensor for outdoor parking lots - as well as the usage of Bluetooth connection between the phone and the sensor network was presented by the authors. An Internet of things (IoT) based parking system with an online reservation capability was presented in [16]. It involves the use RFID tags and readers to verify automobiles for new and existing users. The system performance may also be seen via a web interface. Similarly, in [17], a prototype of intelligent car parking was proposed using a wireless sensor network. The proposed system is built on low-cost sensor nodes that identify and monitor each parking lot's state. Although the prolonged lifetime of tags makes this technology suitable for a wide range of application scenarios, their limited operational range (i.e. up to 10 m) often restricts the usage of RFID-based solutions to item identification and tracking in relatively small regions. In [18], an IoT innovative system was suggested to provide a parking slot assignment and route navigation system. It employs a novel algorithm for assigning vehicles to their desired destination to the closest vacant parking slot using Dijkstra's algorithm for determining the best route within the parking lot. The user interface was designed as a mobile application for drivers to schedule and receive parking space allocations. However, the use of ultrasonic sensors incorporates some disadvantages, due particularly to their sensitivity to temperature changes and extreme air turbulence. This inspired the current research presented in this article, which examines the design and implementation of a novel IoT-aware Smart Parking System (SPS), which provides users with real-time parking lot availability and the flexibility to accommodate various user preferences. We also provided an exploratory study based on data collected between February and November 2021. This study aims to contribute to Oulu's strategic development plan and smart city development concept.

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III. SMART PARKING SYSTEM DESIGN

The functional elements of the overall smart parking system are illustrated in Fig 1. The placepod sensors were placed in 10 different locations to detect the presence or absence of a vehicle in the parking space. The sole purpose of these sensors is to transmit the data packets into the network via the Long Range Wide Area Network (LoRaWan) protocol, which contains information related to the parking space. Later, the gateway device capable of receiving LoRa wan packets communicates the packets to the endpoint. In our case, the endpoint is a message broker which subscribes to the packets via pub/sub protocol. The broker is only limited to receiving data packets. Therefore, the script is implemented to aid the storing process. It runs on the cloud server to collect the packets from a broker and store the information in the database. The server script decrypts and pre-processes the data packet information before storing it. At last, the user interaction took place using the Representational State Transfer (REST) services. The Application Programmable Interface (API) is created to establish the connection between the REST service and mobile application.

More elaborated details of data communication are presented in the section below.

A. Sensor Placement

In this small-scale study, ten in-ground Place pod sensors were installed on the premises of the University Oulu parking area. The actual position of the sensors can be seen in Fig 2. The green circles represent the sensor deployment positions, accompanied by the number labels, which in turn, are associated with their parking positions. PlacePod sensors are high-precision smart parking sensors and designed to be used in municipal and private parking management systems. Due to the reliability of the generated signals regardless of the weather conditions, low latency, ubiquitous nature, and long-life battery (10 years), they can be ultimately integrated into robust smart parking solutions in real-time. PlacePod PNI sensor consists of an inductor with a saturable core that offers stable and precise measurements regardless of environmental factors such as snow or rain.

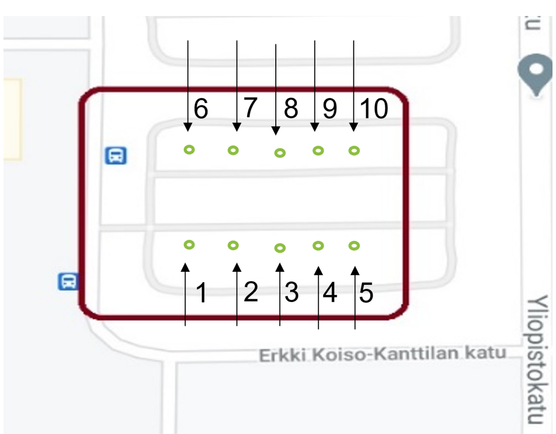

Figure 2. Sensor Positions Area.

B. Data Communication Protocols for Data Acquisition

This section elaborates on the protocols of data transmission to acquire data.

1) LoRaWan (Sensors to Gateway): Fig 3 illustrates the communication pattern between the in-ground Placepod sensors and the installed gateway devices. LoRaWan is a low-power wide-area networking protocol, explicitly designed for battery-operated devices that wirelessly connect to the Internet on a regional, national, or global scale. This supports vital Internet of things requirements. Place pod sensors are built-in LoRa® radio that communicates to a gateway. Our sensors were configured and activated with network AppEUI and Appkey and transmit data packets every 1 min interval. The 5G network of the University of Oulu was used for data transmission.

2) Message Queuing Telemetry Transport (MQTT) protocol (Gateway to Message Broker): The data communication between gateway and message broker is handled on MQTT protocol. Usually, the core of MQTT protocol is the publish-subscribe model, which is distinguished from a client-server model. It separates the client (publisher) who sends the message from the client (subscriber) who receives it. The fundamental of it is that an intermediate role called a broker is responsible for all message routing and distribution. The gateway acts as a publisher that transmits data packets to the message broker. We have purchased a cloud MQTT online service to act as a message broker and subscribe the data packets as a message.

3) Rest API (Cloud Server to Mobile Application): The Rest API was implemented to handle the communication between the database and mobile Application. Representational State Transfer Application Programming Interface is more commonly known as REST API web service. When a RESTful API is called via uniform resource locations (URLs), the server will transfer a representation of the requested resource's state to the client system. In our case, the mobile application act as a client, which requests the server based on some parameters. The request is passed to the server through the Restful API.

Table I
TABLE TYPE STYLES

Action/filter Records	**Query Request URL**
Individual Sensor	/api/v1/resources/Sensors?id="
Datewise	/api/v1/resources/Date?date="
Sensor and Datewise	api/v1/resources/DSensor?deviceid="&date="

The server then responds to the client's request based on the query requested. The primary request URLs are presented in Table 1. Currently, the server is implemented to handle three requests, as demonstrated in the Table 1. For instance, if the user demands to view the record of only one parking space, the request URL mentioning the ID of the sensor would be queried to the server. Similarly, if the user wants to view the sensor's record pertaining to some time interval or a fixed date, then the query based on date wise will be forwarded to the server for fetching the records.

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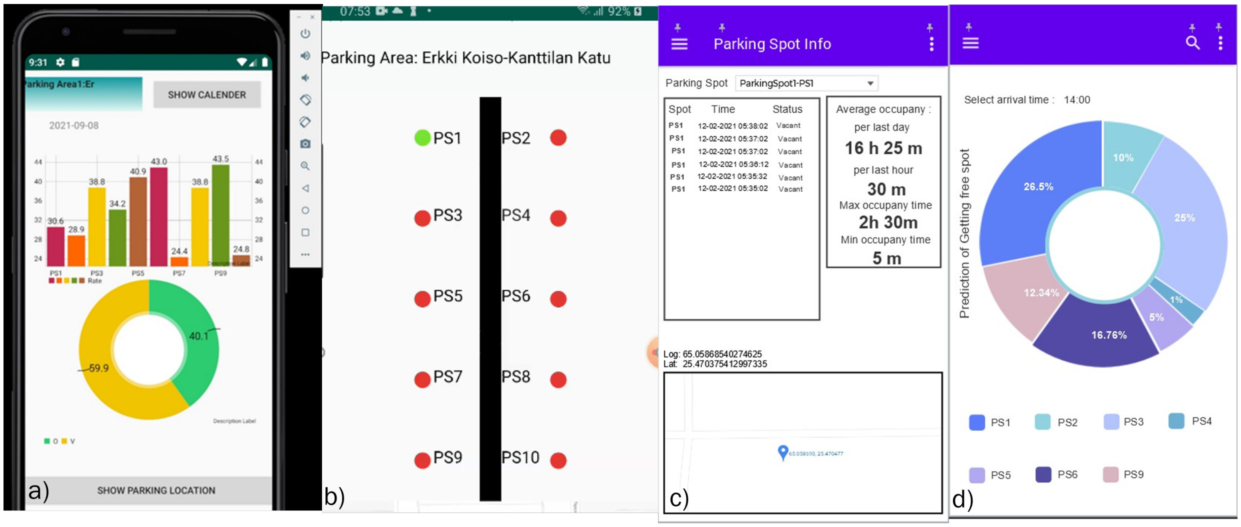

Figure 3. Occupancy rate of parking space and area on daily basis, Real time status of parking space, history of parking spots and prediction.

IV. MOBILE APPLICATION (USER INTERACTION)

The android application is developed to facilitate the user interaction. One of the main features of the mobile application is to provide the user with the report of the occupancy rate of each sensor on a daily basis and the overall parking area, as shown in Fig 3. Similarly, another feature of the application is that the user can be aware of the real-time situation of the parking area and space. In Fig 3, the green spot indicates that the parking space is vacant and can be used for parking. Likewise, the red spot highlights the occupied parking spaces. The mobile interacts with the server using REST API protocols. The application sends the request to the server, which further communicates with the database to fetch the records based on the query provided by the user via mobile application.

V. RESULTS AND ANALYSIS

The exploratory study is carried out on the dataset collection between February 2021 and November 2021 at University of Oulu car parking premises. We have considered the occupancy rate based on different use cases, such as, overall aggregated occupancy rate of days during the months, aggregated occupancy rate during months, aggregated occupancy rate on time window of 30 minutes, aggregated occupancy rate at different sensor positions.

As presented in Fig 4, for case 1, the findings indicate that the overall occupancy rate is high during the months 6th, 11th, and 28th days. Therefore, the possibility of finding vacant space during these days is low compared to other days, such as 5th, 15th, and 17th, where the overall occupancy rate is low.

Similarly, for case 2 considering the aggregated occupancy rate of months. Fig 5 shows that the rate is low during 5th, 6th, and 7th month. This is because of summer season and generally, the people are on vacations in these months

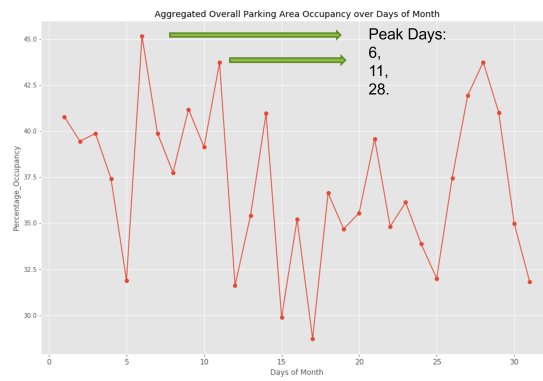

Figure 4. Aggregated occupancy rate over days of month.

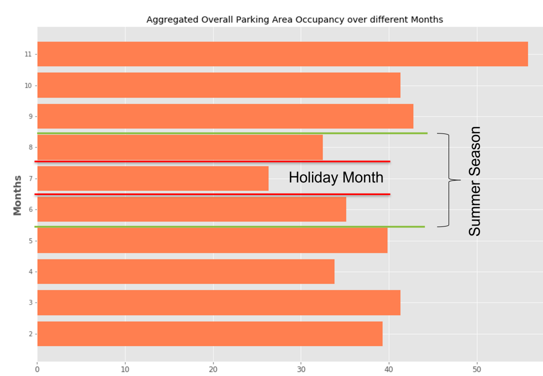

Figure 5. Aggregated occupancy rate of different months.

For case 3, our results validate that the peak hour of parking is during office hours, as shown in Fig 6. The gradual increase in occupancy rate starts from 7:00 till 16:00 and decreases on wards 16:00. The chances of getting vacant space are more after 16:00. For case 4, the findings indicate that the parking space equipped with sensor 10 is mostly occupied compared

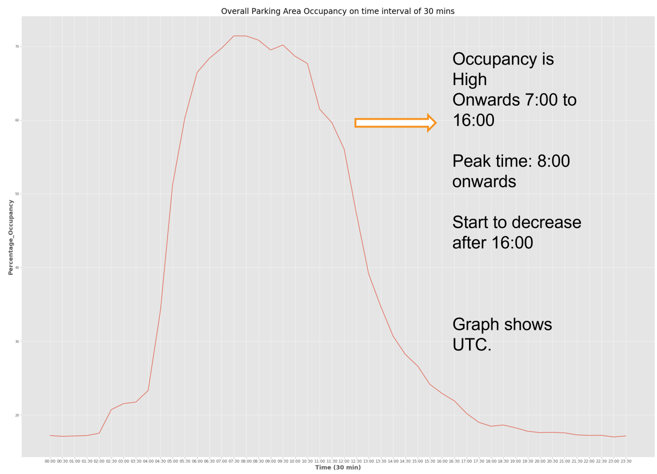

Figure 6. Aggregated occupancy rate of time interval (30 mins).

to other parking spaces. The actual reason for that is not known. However, the chances of parking in this space are low compared to other spaces. Fig 7 illustrates the aggregated occupancy rate of various sensor positions.

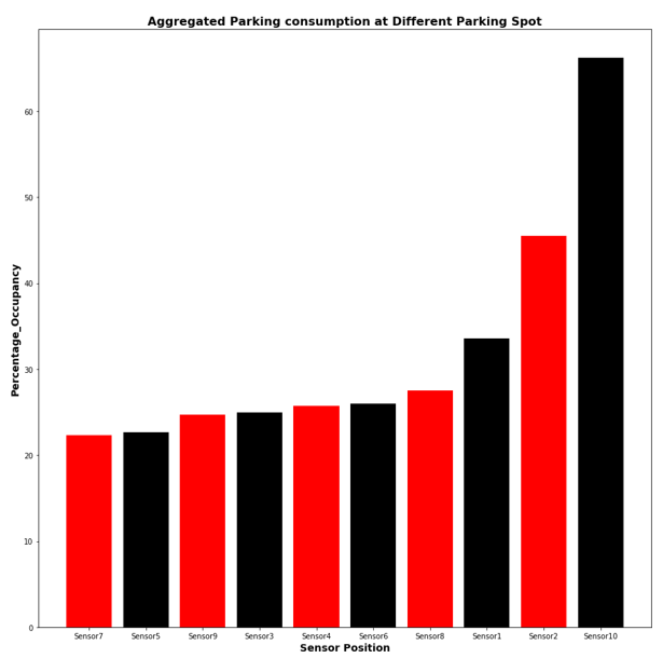

Figure 7. Aggregated occupancy rate of Sensor positions.

VI. Conclusion

In this paper, we have presented the deployment of an IoT-based smart parking system that can collect parking space information and convey it to users, contributing to minimizing traffic congestion and enhancing well-being standards. The main novelty of the proposed approach lies on the context of scalability, where the sensor nodes can be integrated with the existing system and the introduction of a mobile application that can predict the parking availability in advance.

Local gateways were used to assure scalability. Furthermore, the gateways include an open, modular, adaptable, scalable, and transformational hardware and software design, enabling authorities and operators to swiftly implement traffic control and monitoring methods employing Information Technology Services (ITS) cooperative technologies. The findings showed and validated that the occupancy rate is at its peak during office hours, and low occupancy rates were found throughout holidays, especially during the summer seasons. Similarly, the maximum occupancy was observed in November compared to other months. Another interesting finding is that some days of the months have found to have a high percentage of occupancy compared to other days. For future perspectives, our investigation will be extended to explore the seasonal variations of occupancy rates.

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