Smart parking solutions: a comparative study of parking space subleasing models in smart cities

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Abstract
In the dynamic landscape of smart cities, efficient parking management is crucial. This article explores innovative approaches to subleasing parking spaces, drawing inspiration from the Airbnb model. The objectives outlined here include defining a framework for smart parking solutions, analyzing previous research on urban mobility and digital platforms, presenting key findings on the effectiveness of various subleasing models, discussing implications for urban planning and mobility, and highlighting the unique value of the proposed approach. This article aims to lay the foundation for providing a conceptual and practical framework for smart parking solutions, paving the way for the implementation of a sustainable and efficient model in urban parking space management. This approach not only offers practical solutions but also shapes a vision for the future of smart cities, emphasizing how technology can significantly contribute to optimizing mobility and quality of life in urban environments. The proposed application is specifically designed for individuals who have parking spaces allocated by the municipality and wish to sublease them. In conclusion, the detailed analysis of different parking space subleasing models provides positive insights into their efficiency and optimization.

Keywords: smart cities, parking solutions, urban mobility, digital platforms, subleasing models.

1. Introduction
In the past few decades, rapid urbanization and population growth have exerted increasing pressure on city infrastructure, as evidenced by global forecast reports [1]. In the context of this ever-changing urban landscape, the concept of the smart city has become an essential solution for efficiently managing resources and improving the quality of life for residents. Within this framework, one of the major challenges remains the proper management of parking, emerging as a critical aspect of urban mobility.

To address this type of issue, major cities are attempting various measures to make the city as smart as possible and make use of all available resources [2], such as rational land-use planning, the construction of new parking structures, and the development of intelligent software applications.

By promoting the efficient use of parking resources, these models contribute to reducing traffic congestion, thereby decreasing greenhouse gas emissions generated by moving vehicles. They also provide drivers with the ability to quickly find parking spaces, minimizing time spent searching and contributing to fuel savings and a reduction in pollutant emissions.

The purpose of this study is to explore and analyze innovative models for subleasing parking spaces within smart cities. In this context, the proposal is to define a conceptual framework for intelligent parking solutions, with a focus on efficiency and optimization of urban parking space utilization. This article not only suggests practical solutions but also outlines a vision for the future of smart cities, highlighting how technology can significantly contribute to optimizing mobility and improving the quality of life in urban environments.

1.1. Motivation

Parking, especially in urban areas, is an ongoing struggle and competition due to the limited number of available parking spaces [3]. As presented in the 'Vehicles in Use' report by the European Automobile Manufacturers' Association (ACEA) [4], the number of vehicles in use in the 27 EU member states, plus Iceland, Norway, and Switzerland, continues to rise and increased by 6.69% in 2021 compared to 2017 (Figure 1). If we take a look at land utilization in large cities in America, we can observe that parking coverage in San Francisco is 31%, in Los Angeles it's 81%, and in Melbourne, it's 76% [5]. Therefore, solutions need to be found to help cities address traffic congestion by providing smarter solutions for residents based on their needs. This can involve modifying existing parking spaces, constructing more multi-level parking structures, or finding ways to sublease existing spaces, whether they are public or private.

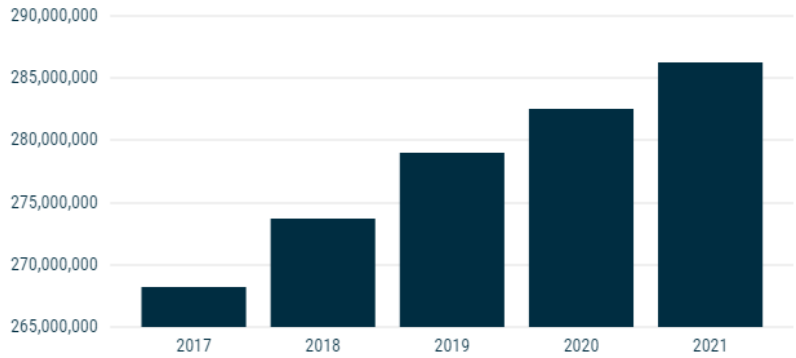

Fig. 1 The number of vehicles in use in the report presented by ACEA in the year 2023
Source: https://www.acea.auto/publication/report-vehicles-in-use-europe-2023/

The central aim of this research is to make a significant contribution to the development of smart cities by addressing a critical need of the population regarding the management of urban mobility. Increased congestion and shifts in people's preferences necessitate not only adaptation to new realities but also anticipation of future needs. In this context, the present study seeks to fill this gap by exploring and analyzing innovative models for subleasing parking spaces, drawing inspiration from the Airbnb model, known for its adaptability and efficiency in the realm of subleases. The proposed parking space subleasing model not only optimizes the efficient use of urban space but also promotes a sustainable and environmentally friendly urban environment.

At the conclusion of the literature analysis, a solution will be proposed to address the societal issue of traffic congestion. This solution involves granting individuals with private parking spaces allocated by the municipality or personal land the right to sublease their parking spaces or land to clients for a specific period through a mobile application.

2. Related work

In recent years, specialized literature has evolved to provide innovative solutions for designing a comprehensive information system regarding parking availability

management. These solutions cover various aspects, including the implementation of a parking reservation system, the development of parking occupancy detection technologies, and the efficient management of the entire process [6].

In the study presented by Jennath HS and his colleagues [3], it is observed that they proposed a solution to address the issue of limited parking spaces. They introduced a platform developed on Blockchain to lease underutilized lands by their owners to a winning agency. This agency would invest in developing the land and then lease it through a platform. Essentially, non-fungible tokens would be created for the parking spaces on the respective land, which would be transferred to the account of the leasing agency. The revenues would be distributed among the owner, agency, and government at the end. Initially, the agency takes the largest percentage of revenues to cover the investment, and then the percentages for the owner's revenues increase. The reason for choosing Blockchain for this project is that it is a distributed ledger technology that uses a consensus mechanism, allowing for trust, transparency, and data immutability [7].

Another study was conducted by Bassma Jioudi and colleagues [8], where they introduced a new architecture for intelligent parking based on multi-agent functions. Among the challenges addressed were the utilization of land, occupancy of public space, economic impact, and pedestrian safety. The system assigns optimal parking for a driver based on the chosen destination and a walking tolerance radius, with reservations created strictly online through a dynamic pricing policy. The proposed concept aims to enhance the driver's experience by combining real-time prices with reservation-sharing services. It was observed that static rates generally encourage the search for free or inexpensive parking spaces, while dynamically setting accurate hourly rates will determine how long a vehicle is parked. The development of the system involved multiple agent roles that depend on each other. Although the objectives of this study were achieved, the conclusion was drawn that the application could be further developed, with the desire to implement the option of drawing the driver's attention to public transportation alternatives.

A third study was conducted by Yi Liu [9], where an attempt was made to mathematically establish the relationship between the social benefits of the city and public parking fees. The study also aimed to observe whether shared parking (private parking owners, companies, hotels, individuals), complementary to public parking, alleviates the challenging parking issues in the city. For the study, the ideal scenario was considered where the number of travelers subjected to the test was fixed. Everyone had to depart from a specific point and reach the same destination, and they could travel by bus or car, excluding other means of transportation. The study's conclusion was that as parking fees increase, total revenues also increase, including parking fees and bus fares. However, for achieving maximum social benefits, urban public agencies need to develop an optimal price for each time interval.

Other studies [10] [11] have attempted to focus on the implementation of various types of sensors to accurately detect when a vehicle is about to park or to track it as it moves, indicating users where to park. Object recognition was performed through computerized techniques for identifying objects in images or videos by training models that learned the

inherent characteristics of the objects. In addition to the use of sensors and object recognition, one study successfully built a system aimed at assisting university staff in quickly and easily reserving a parking space in advance, to avoid wasting time and fuel when arriving at the campus.

The survey conducted by Trista Lin, Hervé Rivano, and Frédéric Le Mouël [5] aimed to comprehensively review the specialized literature from the period 2000-2016 regarding parking solutions. The goal was to observe the technologies applied to the development and evolution of parking, analyzing in detail all categories of sensors used, the network through which information was collected, types of patents registered for parking meters, payment methods, and driver guidance methods. As a result, they summarized the main methodologies used in existing works and their vision for addressing current parking-related challenges.

Following a careful analysis of various previous research on urban mobility, digital platforms, and associated technologies, the proposed approach aims to integrate technologies already used by other researchers in the development of smart parking, adding a distinctive element by focusing on interaction with individuals. The application suggests a dedicated solution primarily for individuals who have a parking space allocated by the municipality, providing them with the opportunity to sublease it in a manner similar to renting an apartment through the Airbnb platform.

Essentially, the application proposes the use of sensors placed on parking bollards to detect the presence of vehicles. Users can then make online reservations based on the availability of parking spaces. This approach represents an innovation in how smart parking interacts with the community, adding efficiency and simplifying the parking space management process.

3. Proposed work

The proposed application focuses specifically on the needs of individuals who have parking spaces allocated by the municipality and wish to make them available for subleasing during periods when they remain vacant or unused. By providing owners with the opportunity to sublease these spaces when not in use or unoccupied, the application contributes to the creation of a smart and sustainable urban environment.

The account validation within the application involves providing clear proof of ownership through a specific request. After this step, the process continues with the installation of the system and the creation of the actual announcement for subleasing the parking space. This initiative not only optimizes the efficient use of available parking space but also has a positive impact on the concept of a smart city.

By facilitating the subleasing of unused parking spaces, the application contributes to reducing carbon dioxide emissions, lower fuel consumption, and the decrease in the number of unauthorized parking. Thus, in the context of a smart city, this solution represents a step forward towards a more efficient and sustainable urban community, alongside other existing solutions on the market.

3.1. Software development and application logic

The software part proposes an application based on a client-server architecture. On the client side, we have a mobile application developed using React Native technology, serving as an intuitive interface for users. On the server side, Express.js will be employed with a MySQL database to manage parking and reservation-related information.

From the perspective of the parking space owner, they need to authenticate themselves in the application, providing various personal details, including proof of the contract with the municipality to verify ownership of the parking space. Subsequently, after verification and approval, the owner must submit a request indicating whether they want to continue with the process and whether they wish to use the parking system provided by the company.

If the owner chooses not to use the system for various reasons, such as already having a traditional parking barrier or not wanting to secure it in any way, the next step is to create a listing for the parking space. This involves adding details such as the address, photos, other essential information, and the price. If the provided system is not used, the owner will need to come in person each time to unlock the parking space for customers and lock it again at the end.

If the owner chooses to use the system, to facilitate the implementation and reduce the efforts of the customers, a specialized team will travel to their location at the time of purchase or rental of the system. The team will be responsible for installing the equipment and establishing connections, ensuring a seamless and hassle-free experience for users. This way, the proposed solution brings innovation to parking management, efficiently combining software and hardware technologies to meet the current needs of modern users. From the user's perspective, they could search for the destination they want to reach and check the available parking spaces during the selected time interval, making a reservation in advance. When they arrive at the destination and are within 50 meters of the barrier, they can press a button in the application to request the barrier to be lowered. When they are ready to leave and vacate the parking space, they will need to use another button to indicate their departure, making the parking space available again.

3.2. Hardware development and communication logic

The hardware component consists of a gateway (with wireless connectivity to the internet) and the parking barrier with batteries. The operational logic involves having a radio module mounted on the parking barrier, enabling communication with the gateway installed in the owner's house or apartment through a LoRa protocol-based radio connection. This allows the parking barrier to be placed at significant distances from the location of the gateway.
It is essential for the parking barrier to integrate magnetic sensors and laser parking sensors. The choice of these sensors is due to their ability to provide accurate and comprehensive information about the status of parking spaces. Magnetic sensors detect the presence of vehicles through changes in the magnetic field, providing a reliable indication of parking space occupancy or availability. In parallel, laser sensors measure the distance between vehicles, ensuring detailed information about the available space.

The integration of these advanced sensors contributes to optimizing parking space management and providing a precise and efficient experience for users. A built-in radio module in the barrier is imperative to facilitate seamless communication between the barrier, gateway, and the application server. This radio module ensures the efficient transmission of data collected by sensors to the gateway and, consequently, to the server, strengthening the real-time operation of the system and providing a quick response in access control and parking management operations.

The LoRa protocol is designed as a low-power, long-range network solution specifically tailored for Internet of Things (IoT) devices. This protocol facilitates efficient data transmission and reception in small quantities over long distances, all with low energy consumption [12].

In the context of using a parking barrier, it can communicate with a gateway mounted in the owner's house or apartment, benefiting from the efficient functioning of the LoRa protocol over considerable distances via radio waves. Thus, the barrier and gateway can exchange information and transmit or receive data to and from the server.

The gateway plays a crucial role in facilitating the connection between the parking barrier and the application server. When the server issues a command to release the barrier, it must send a corresponding request to the gateway's IP address over the internet. The gateway receives this command and transmits it to the barrier via radio waves. This detailed interaction between hardware and software components is illustrated in Figure 2, as presented in the article by Changqing Sun and colleagues [12], providing a clear perspective on each step of the communication process between systems.

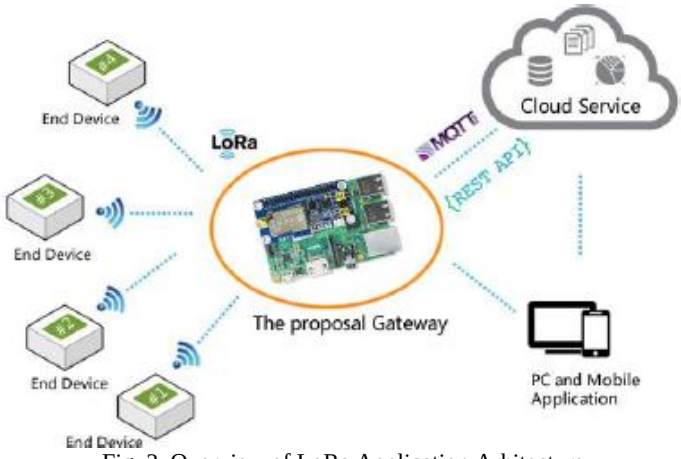

Fig. 2. Overview of LoRa Application Arhitecture
Source: https://sci-hub.se/10.23919/CCC50068.2020.9189480

Security of communication between the parking barrier, gateway, and server is paramount in the context of smart cities. By employing advanced encryption, multi-factor authentication, and HTTPS protocols, the system ensures the confidentiality and integrity of transmitted data. The implementation of continuous monitoring mechanisms, along with

regular device updates, including vulnerability management technologies, complements security efforts. Solutions against Man-in-the-Middle attacks and well-defined security policies, such as access management, add an additional layer of protection. In this way, a smart and secure urban ecosystem is created, leveraging modern technologies to prevent cyber threats.

4. Estimated results

By exploring and carefully analyzing various technologies available in the field of smart parking, this study has provided a detailed perspective on the current technological landscape. Through this research process, key technologies and principles were highlighted, serving as catalysts for shaping a clear vision of the future direction of my project.

The study has helped me compile a concise summary of the most used technologies and principles in the realm of smart parking. It has had a significant impact on my conception of how my parking space subleasing application should be designed. In particular, I have identified essential elements that can contribute to creating an innovative and efficient application.

I believe that integrating this application into the context of existing technologies for our city can transform urbanization into a smarter and more sustainable experience. By providing a parking space subleasing system tailored to the specific needs of our community, we can contribute to optimizing resource utilization and developing a more connected and efficient city.

This research and technological implementation direction not only bring individual benefits but can also contribute to collective progress towards a smarter and more environmentally friendly urban community.

5. Author's contribution

My involvement in this study consisted of a meticulous and detailed approach to the literature and other relevant sources in the field of smart parking. Specifically, I deepened my understanding by summarizing and synthesizing information obtained from various articles and studies related to this subject. This crucial stage of the process aimed to draw conclusions and identify key trends in smart parking technologies.

Through careful analysis of existing literature, I was able to formulate a clear perspective on emerging technologies, significant issues, and proposed solutions in the field. This solid foundation was essential for developing a robust conceptual framework and suggesting an innovative model for the parking space subleasing application.

My proposal for a parking space subleasing application by owners is based on conclusions drawn from the literature, adapted to the specific needs of our community. This involvement is reflected in the efforts to create a practical and efficient solution that not only addresses existing challenges but also contributes to the evolution towards a smarter urban infrastructure.

6. Conclusion and future perspectives

The research and meticulous analysis of smart parking technologies have culminated in the formulation of an innovative proposal: a parking space subleasing application for owners. This initiative was grounded in a profound understanding of relevant literature and other resources.

My involvement focused on synthesizing information from various sources to draw essential conclusions, thereby guiding the development of a practical solution. The proposal is rooted in the community's needs and aims to contribute to the evolution toward a smarter urban infrastructure.

In the future, practical implementation will provide relevant data for the continuous optimization of the application. Collaboration with the community and the integration of emerging technologies are essential steps for adapting and continuously improving the solution. Exploring how the application can contribute to sustainability and urban efficiency opens new perspectives for smart urban development. These efforts are crucial for transforming the concept into a beneficial reality, contributing to the improvement of the quality of life in our city.

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