



SMART PARKING IN INTERNET OF THINGS URBAN CITIES

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Abstract- The prompt population expansion has led to ample traffic blockages in recent transportation structures. This not only causes substantial air pollution and waste in time and energy, but also denotes the matter of the auto-park inadequacy. In the age of IoT (Internet of things) and Smart city networks, smart parking and appropriate advanced solutions are necessary towards more maintainable future cities. Smart parking with the help of sensors implanted in cars and city infrastructures can ease the blocks in parking problems and provide the best quality of services and profit to citizens. However, several design aspects should be well investigated and analyzed before implementing such solutions. In this paper, it is mentioned that classifying the smart parking systems while considering soft and hard design factors. The overview of enabling technologies and sensors which have been commonly used in the literature. The highlights on the importance of data reliability, security, privacy and other critical design factors in such systems. Rising parking trends in the ecosystem are investigated, while focusing on data interoperability and exchange.

1. INTRODUCTION

The idea of smart parking was familiarized to solve the problem of parking space and parking management in megacities. With the escalating number of vehicles on roads and the inadequate number of parking spaces, the congestion of vehicles is expected. This congestion would lead to driver aggression as well as environmental pollution. These factors may worsen particularly during peak hours where the flow density is at its maximum, locating a vacant parking spot is near to impossible. A recent report by INRIX shows that on average, a typical American driver spends 17 h a year looking for a parking space. However, looking at a major city such as New York this figure is much higher. According to the report, New York drivers spend 107 h per year searching for parking spots. Taking into account the amount of fuel spent during this period, significant levels of the emissions and the harmful gases are expected to appear. Identifying these problems and trying to resolve them in a manner that is effective and at the same time sustainable is a puzzling task.

In the framework of a smart city ecosystem, inputs from elements such as vehicles, roads and users have to be networked and analyzed together in order to provide the best service in fast and secure manners. One of the reasons for marching towards a smart city ecosystem is to use the potential of existing technologies and infrastructures in providing the best utility to users and improving their future. With the help of IoT applications, mobility and transportation are considered to be the key influencing factors in sustaining our surrounding environments, especially those which utilize intelligent transportation systems.

One of the key components in intelligent transportation systems (ITS) is the Smart Parking System (SPS), which relies significantly on analyzing and processing the real-time data gathered from vehicle detection sensors and the radio frequency identification (RFID) systems that are placed in parking lots to report the absence and/or presence of a vehicle. These sensors have their strengths and weaknesses in certain areas where they are deployed.

Moreover, security and privacy issues of the data transmitted and/or received must be carefully treated. Several factors such as communication and data encryptions must be well investigated in advance before implementing such systems. These subjects have to be seriously considered as the data collected from these sensors might be used in several critical scenarios such as, the parking space prediction in emergencies, and the path optimization in self-driven cars. Any vulnerability in these scenarios, no matter how significant/insignificant they are, can potentially lead to personal information leakage and increase the risk of security attacks. Considering the aforementioned aspects can significantly enhance the experience of both; the parking lot operators (by maximizing their revenues), and the SPS users (by easily searching, booking and paying in advance for their parking lot). Accordingly, any smart application in the current smart city ecosystem has to be context-aware and has to adapt dynamically to contiguous changes.

2. SMART PARKING SYSTEMS AND CLASSIFICATIONS

Smart parking systems are categorized into various categories in which each of them has a different purpose and use different technologies in detecting vehicles. Smart parking systems benefit both the drivers and the operators. Drivers use the system to find the nearest parking spots and the parking operators can utilize the system and the collected information to agree on better parking space patterns and a better pricing strategy.

Smart parking enables several attractive services such as the smart payment/reservation, which can substantially enhance the experience of both drivers and operators. Furthermore, SPS can play a significant role in providing a clean and green environment by minimizing the vehicle emissions via decremented delays in finding the vacant parking spot.

Smart parking system (SPS) architectures commonly consist of several layers based on their functionalities. Firstly, the sensing layer, which is the backbone of the smart parking system, and it is responsible for detecting the presence and/or absence of a vehicle in an area using different sensing technologies. These technologies are mostly comprised of receivers, transmitters, and anchors. Secondly, the network layer, and it is the communication segment of the system, which is responsible for exchanging messages between transmitters/receivers and the anchors. Thirdly, the middleware layer, which is the processing layer of any SPS in which intelligent and sophisticated algorithms are utilized to process the real-time data. It also acts as a data storage, as well as, the link between the end users requesting services from the lower layers. Finally, the application layer, and it is the top layer in the system, which interfaces the SPS with clients (end-users) requesting different services from different mobile and/or stationary information panel.

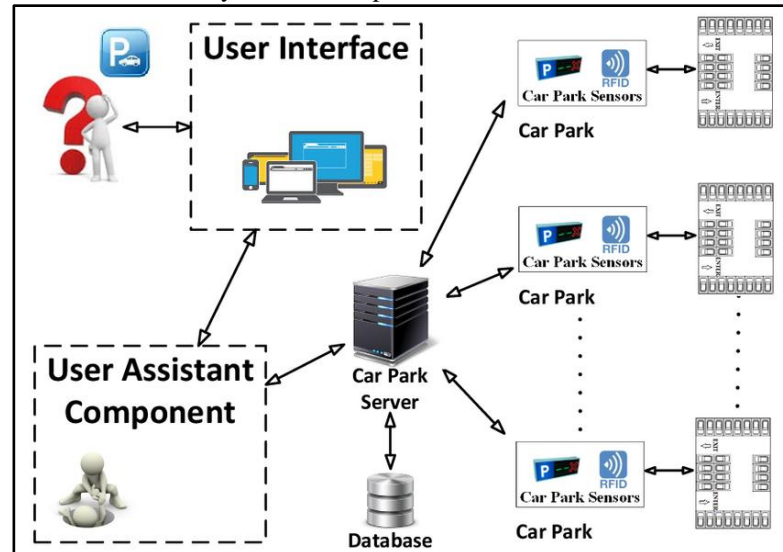


Figure 1: Smart parking system architecture
(Source: Research Gate)

These multilayered parking systems can be categorized into the following three types.

2.1. Centralized-assisted smart parking systems

In centralized smart parking systems, a single central server collects the necessary parking information and process it to provide services such as the parking lot reservation, allocation, and/or driver guidance. The following sample systems are generally implemented as a centralized system.

2.1.1. Parking guidance and information system (PGIS)

PGIS or also known as Advanced Public Transport System (APTS), works by collecting parking information dynamically from loop detectors, ultrasonic, infrared, and microwave sensors in order to inform the drivers in real-time manners about the vacancy of the parking lot via an onboard guidance system or a variable message sign (VMS). PGIS consists of four major subsystems namely; the information collection, processing, transmission, and distribution. PGIS can be implemented in both; citywide and/or individual parking lots, where in both cases, drivers can easily follow and navigate to reach the vacant parking space a combination of PGIS and Dedicated Short- Range Communication (DSRC) is presented, where the DSRC-based PGIS provides a real-time, rapid and efficient way of guidance. However, concerns regarding the PGIS algorithm efficiency and the data safety, as well as, the need for incorporating heterogeneous smart subsystems may cause severe issues in the implementation stage.

2.1.2. Centralized assisted parking search (CAPS)

In this example, the First Come First Serve (FCFS) approach is adopted, where the first requester vehicle is guided towards a guaranteed vacant spot closest to the driver location. However, in this manner, other vehicles waiting in the queue are in continuous movement until the server can satisfy them. This brings the issue of uncooperativeness between drivers that can significantly degrades the performance in CAPS. Furthermore, the high maintenance cost and scalability are serious concerns in CAPS, as well.

2.1.3. Car park occupancy information system (COINS)

COINS utilizes video sensor techniques based on one single source to detect the presence and/or absence of vehicles. The status is then reported on information panels which are strategically placed around the parking lot. COINS is mainly dependent on four different technologies: 1) the counter-based technology, 2) the wired sensor-based technology, 3) the

wireless sensor-based technology, and 4) the computer-vision based technology. Knowing that, using the last technology can provide more accurate results about the exact status of the parking spot without deploying other sensors in each individual spot, COINS was developed and simulated in different environments with different parameters such as weather conditions and illumination fluctuations, which can add an extra layer of complexity to the system.

2.1.4. Agent based guiding system (ABGS)

ABGS simulates the behavior of each driver in a dynamic and complex environment explicitly. The agent in this system is capable of making decisions and define the interaction between drivers and the parking system based on perceived facts from the driver and other varying aspects such as, autonomy, proactivity, reactivity, adaptability, and social-ability. For instance, SUSTAPARK was developed to enhance the searching experience while locating the parking space in an urban area with an agent-based approach. The authors aimed at dividing the parking task into manageable sub-tasks that the computer agents could follow using Artificial Intelligence (AI) techniques. Another agent-based approach was introduced in named PARKAGENT, based on ArcGIS with similar functionalities to SUSTAPARK. However, it considers the effects of the system entities' heterogeneity and the population distribution of drivers.

2.1.5. Automated parking

Automated parking consists of computer-controlled mechanical systems which enable drivers to drive their vehicles into a designated bay, lock their vehicles and allow the automated parking system to manage the rest of the job. Stacking cars next to each other with very little space in between, allows this system to work in an efficient way such that the maximum available space in the parking is utilized. The retrieval process of the vehicles is as easy as entering a pre-defined code or password. The process is fully automated, which adds an extra layer of security and safety to the whole system including both drivers and vehicles. Although the initial cost of automated parking is very high, however, for the services that you receive, the price is very competitive. In fact, 50% saving compared to conventional modes of the parking in locations, where the parking fee is high and time-limited, is expected. In these systems, employment of one or a combination of many services and sensors may be integrated to provide a fast, reliable, and a secure mode of parking with little or no interactions between the drivers and the system.

2.2. Distributed-assisted smart parking systems

In distributed smart parking systems, many services are connected and are controlled by a single server. This is well explained in vehicular networks where one vehicle can exchange information to one or more vehicles effectively creating a distributed network of vehicles. Another example is in the systems where information processing and dissemination is generally based on roadside infrastructure. Examples below are considered as distributed and opportunistic smart parking system in the literature.

2.2.1. Transit based information system (TBIS)

TBIS is a park- and ride- based guidance system with similar functionalities to PGIS. It communicates with drivers through VMS to guide them towards a vacant parking spot. It also provides a real-time information about the public transportation schedules/routes status, which enables drivers to pre-plan their journey more efficiently. A field test in San Francisco shows promising results for the effectiveness of TBIS. However, due to the initial capital cost, such a system should be implemented mainly in large-scale applications to recover the cost. Geographic Information System (GIS) is also another way for providing traffic information to users.

2.2.2. Opportunistically assisted parking search (OAPS)

Vehicles with IEEE 802.11x communication standard in ad-hoc mode can share information about the status and location of the parking spots. This enables drivers to make more knowledgeable decisions, while they are searching in the crowd. In this approach, drivers are guided toward the closest vacant parking space by analyzing timestamps and geographical addresses using GPS units, for example. Since OAPS dissemination service does not impose a global common knowledge about the status of parking spots. The outdated timestamps and infrequent updates could cause delays and intimidate the effectiveness of this approach.

2.2.3. Mobile storage node-opportunistically assisted parking search (MSNOAPS)

Instead of normal vehicle nodes, the inflow of information is channeled through Mobile Storage Nodes (MSNs), which enable information sharing with other mobile nodes acting as a relay between vehicles. Similar issues in data dissemination can also be observed as the status of the parking spot changes overtime. Because the accuracy of disseminated data has a tendency to drop down as the number of relays increases.

2.3. Non-assisted parking search (NAPS)

In NAPS approach, there is no inflow of information from any vehicle/ server. The parking decision is solely dependent on the driver's observation in the parking lot, or on a former experience considering the traffic flow and the time of the arrival in the parking lot. Drivers wander around a parking lot and check for empty spots in sequence until an empty one is found. This

empty spot is then allocated to the driver who has reached the spot first. Usually, it is performed with the minimum technology involvement. That is why we call it, “Non-assisted” parking.

Scalability and cost design issues associated with the aforementioned categories of smart parking systems are mainly justified/claimed by the amount and type of the utilized sensors and/or enabling technologies.

2.4. Use-cases in practice

In this subsection, we outline three common use cases of the smart parking system for a discussion that is more comprehensive. These use cases are named as follows: 1) The Smart Payment System (SPS), 2) The Parking Reservation System (PRS), and 3) The E-parking System. A detailed analysis for these use cases is provided in the following subsections.

2.4.1. Smart payment system (SPS)

Conventional parking meters were always slow and inconvenient to use. Nevertheless, the smart payment system has been developed and integrated nowadays with IoT and advanced technologies that assure reliability and fast payment methods. This system employs contactless, contact, and mobile modes to achieve its purpose. In contactless mode, smart cards and RFID technologies such as Automated Vehicle Identification (AVI) tags are used. In contact mode, credit and debit cards are utilized. In mobile mode, mobile phone services are employed to collect the payment. Internet-connected parking meters can also be used as a tool for the parking patterns determination and prediction, especially for the on-street parking where machine learning techniques are applied.

2.4.2. Parking reservation system (PRS)

PRS is a new concept in intelligent transportation systems (ITS), which allows drivers to secure a parking spot particularly in peak hours prior to or during their journey. The objective of PRS is to either maximize the parking revenue or minimize the parking fee. This has been achieved by formulating and solving a min-max problem. Implementation of PRS requires several components namely: the reservation information center, the communication system between the users and the PRS, the real-time monitoring system for the parking lot, and an estimation for the anticipated demands. Drivers can later use a variety of communication services such as SMS, mobile phone, or web-based applications to make the reservation of a parking space. SMS-based reservation was implemented, where the integration of micro- RTU (Remote Terminal Unit) and the microcontroller, in addition to other safety features make it a smart solution in PRS. Such a system is also scalable and capable of handling multiple requests from drivers. CrowdPark system is another example of PRS proposed, where the system works by crowdsourcing and rewarding to encourage drivers to use the system and report the parking vacancy.

2.4.3. E-parking system

E-parking, as the name suggests, provides a system in which users can electronically obtain information about the current vacancy of the parking lots from other services and sensors. Moreover, it makes reservations and payments all in one go without leaving the vehicle and before entering the parking lot. The system can be accessed via mobile phones or web-based applications. In order to identify the vehicle making reservations, a confirmation code is sent to the user’s email and/or mobile phone through SMS which then can be used to verify the identity of the vehicle. Majority of the smart parking deployments that are introduced in this paper are an example of E-parking where information about the parking vacancy can be achieved in advance.

3. SOLUTIONS IN PRACTICE

In this section, various implementations of the smart parking system is investigated. Other aspects of the smart parking system in smart city applications such as the parking lot management for EV charging stations, and huge city-events which are more complex and broader in size and density have been also discussed and analyzed.

3.1. Implementation of smart parking systems

Various implementations of the smart parking system in the literature based on their vehicular sensors as well as their mode of communication and other relevant criteria are discussed in this subsection and classified into the single vehicle-detection system, versus the large-scale ecosystem.

3.1.1. Single vehicle-detection sensors

A custom infrared sensor was used in to detect vehicles entering the parking spot where the results were sent to the router using Arduino by the mean of a wired connection. Drivers are automatically connected to the parking network and to check for parking spaces, an android mobile application based on JSON was used to determine the vacancy. This system was also used to guide drivers when they are leaving the parking spot, in addition to enabling the smart payments. On the other hand, in authors used Raspberry Pi as the central server to send information to the cloud-based mobile application. In these two examples, the scalability of these systems for multilevel parking lots are of concern where the system reliability and effectiveness are major points to be considered. An example of a reliable implementation is presented in where the system is comprised of both passive infrared and magnetic sensor to detect vehicles. The collected information was sampled in Java

using TinyOS-2.x and the results were reported to drivers in a web-based application. A smart parking system for commercials stretch in cities using passive infrared sensors and image detectors was discussed. It also introduced smart payment and reservation system in addition to guidance using GPS in mobile applications. Ultrasonic is the most used sensor to detect vehicles in many areas. As presented, the smart parking solution was achieved using ultrasonic vehicles' detection and ZigBee-based communication between the detection sensors and a RabbitCore microcontroller. This SPS uses the shortest path algorithm to find the nearest parking spot and exit location near to the current vehicle location while entering/leaving the parking lot. This SPS requires the drivers to follow the directions given by the system and any deviation results in the failure of the system. Similarly in, ultrasonic sensors were used for detecting vehicles in a multilevel parking lot. However, additional horizontal sensors mounted on the parking walls were used for detection of the improper parking. An alarm would be triggered in order to notify the driver about this improper parking position. In this way, using three sensors per parking spot would not be feasible and further studies should be conducted for cost-effectiveness. Ultrasonic was also used in mobile systems. The ParkNet vehicles in also comprised GPS receivers and mounted ultrasonic sensors on the passenger side doors of the vehicle to detect the parking spot in urban areas.

3.1.2. Smart parking in smart city ecosystem

Existing smart parking attempts in the smart city paradigm are either utilizing a single detection sensor, or they fall in the large-scale implementations. In large-scale scenarios, multiple technologies must orchestrate together in exchanging data to achieve a smooth interoperability between the parking lots in an IoT-based ecosystem. Smart parking in the smart city paradigm can be defined as a system that can facilitate interoperability among its sub services to provide quality of life (QoL) for urban citizens. An example of a complex and large parking system can be the huge city-event parking scenario. Large events, such as sporting events, require many services to work together in order to provide an effective smart parking solution. For instance, the initiative to create an open IoT smart parking ecosystem for FIFA World Cup 2022 (in Qatar). Another concept of a citywide parking lot management is described. By utilizing a novel distributed algorithm and cloud computing, authors provided a smart parking system that is context-aware and can gather information from the city or from the citizens for accurately determining the status and/or predicting the parking vacancy. Towards cleaner environment and more energy savings, electric vehicles (EVs) are now favored worldwide. However, the lack of charging stations and/or their locations have led to severe drivers' inconvenience. Although in the future more homes and offices will be equipped with charging services, the need for a smart system to manage the charging of EVs considering time, location and other criteria should be premeditated. Scheduling such charging stations in the smart same time be profitable to parking owners should be carefully analyzed. In order to integrate and expand the EV charging stations to the smart city ecosystem for full interoperability, like the example stated earlier, careful consideration of using the Open Standards must be made. To address such problems a case study of EV charging station via a mobile application to search and reserve these charging stations in a smart parking system. In the aforementioned examples, seamless integration of the ubiquitous IoT services and technologies must be achieved in order to realize an effective system in the ecosystem. A bi-level optimization of a smart distribution company for the parking lot owners was examined. The optimal scheduling of EV charging stations for the best of the company and the owners, was evaluated by stochastic programming due to uncertainty in the parking lots.

3.2. New applications in smart parking system

In this section, various emerging techniques for the smart parking system have been highlighted and discussed for a more comprehensive study. These techniques can be categorized into VANET versus UAVbased techniques.

3.2.1. Vehicle to everything (V2X)

With the advancement of technology and wireless communication improvements over the years, there has been a new trend in communication technology between vehicles and infrastructures known as VANET or Vehicle Ad Hoc Network, which is a subgroup of MANET or Mobile Ad Hoc Network that uses vehicles as mobile nodes. They are classified into three different types, Vehicle- to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), and lastly Vehicle- to-Roadside (V2R). The mac layer standard of VANET is IEEE 802.11p standard with a connectivity range of 100–1000m and 27.0 Mbps data rate that promises fast and reliable method of communication. However, they are more expensive than other protocols. Onboard Units (OBU) installed in vehicles by manufactures and the Roadside Unit (RSU) installed near the road providing both road safety and a mode of communication between the vehicle and the roadside infrastructure are the requirements in this type of SPS. VANET is also used in smart parking systems where vehicles can detect parking occupancy and report the location to other vehicles or to roadside units in a two-way communication manner.

3.2.2. Unmanned aerial vehicles (UAVs)

UAVs, also known as drones, are also becoming a trend in today's IoT applications. They are mainly used in wireless communication and serve as a backbone for the network connectivity in places where communication range is limited or it fails to work in case of a disaster. Equipping drones with the vehicle detection sensors as discussed previously not only can provide the benefit of having a one-package smart parking system with all the advantages of a regular smart parking system, but it also can overcome the shortcomings of the sensors in certain areas. Larger detection range, ability to carry multiple

sensors, high precision, flexibility in deployment, high mobility and many others, are just a few advantages showing the ascendancy of drones compared to static vehicle detection sensors. A UAV-assisted smart parking example was studied. In this work, authors utilized GAN (Generative Adversarial Network) for detection and prediction of the parking vacancy in a vision-based approach. High precision of their UAVs shows the superiority of their detection algorithm and obstacle avoidance technique.

4. CONCLUDING REMARKS

As the population of urban area increases leading to traffic congestions and other problems, the need for parking spots is inevitable. In the age of IoT and smart city ecosystems, it is not difficult to believe why a smart and innovative solution is considered to pave way towards a more sustainable future for cities. Hence, to improve the current parking system and to address significant issues in overcrowded cities, the smart parking system has been overviewed. Many parameters must be well studied and analyzed before implementing any smart parking system. Therefore, a comprehensive survey of the current state of smart parking systems including classification of the parking system, major vehicle detection technologies and communication module have been presented in this work. The objective of this survey was to offer an insight into new research attempts in the intelligent transportation system. We looked at different elements of the smart parking system and explained thoroughly the hardware and software aspects of this application. Software aspects of the smart parking was presented and several features such as parking prediction, path optimization, parking assignment and how the collected information can enhance the experience of parking operators and drivers, were introduced. Different tables were generated in order to compare several key factors about the main elements in a smart parking system, including sensors and communication modules. Moreover, an overview of the associated data security/privacy, and new trends in interoperability and data exchange have been discussed. Next, emerging technologies in smart parking systems, namely the V2X and UAVs, have been presented. The concept of cloud-based hybrid models has been suggested in order to solve key issues in smart parking applications. As a future work, we plan to further investigate our cloud-based hybrid concept with the help of interoperability and drones in order to provide a proof of concept for the next generation of the smart parking systems.

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