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A New Architecture: Informative Smart Parking System for Smart Cities

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ABSTRACT

Car parking problem has been considered as one of the major issues in our daily life activities. This is due to the increase of the number of cars in the world. Growing the global number of cars increases the demand for parking which in turn needs intelligent and highly efficient systems, providing best practices in car parking operations management. Parking availability prediction and reserving a vacant parking spaces in congested cities are major concerns to many motorists. Therefore, this paper proposes a new smart parking architecture called Informative Smart Parking System. The proposed architecture provides motorists with advance information about parking lots availability in real-time basis. It also provides motorists with availability parking suggestions without the need to install sensors. The development of non-IoT smart parking systems will help to facilitate the smooth transition from conventional parking system infrastructure to digital transformation era which is entirely equipped with IoT. In addition, a mathematical model is provided to calculate the number of available parking spaces based on arrival time prediction. This model is a novel attempt to predict the available number of parking spaces at any expected arrival time.

Key words: IoT, Parking architecture, Sensors, Smart parking systems, Smart Cities, systems architecture

1. INTRODUCTION

The number of vehicles on roads has been increasing rapidly and significantly, resulting in traffic congestions in big cities. Most of the times, especially in peak hours, finding vacant parking spaces is frustration and tedious task to many motorists. It also increases fuel consumption, air pollution and increases traffic congestion up to 30% as well as wasting drivers' time [1 – 3]. More adequate and effective smart car parking solutions are needed to overcome such challenges facing motorists, city councils and parking operators.

Smart cities benefit from the rapid development of digital technologies to improve people's lifestyle. Parking prediction systems diminish the cruising time needed to look for parking spaces as well as reducing congestion in urban areas are required as an integral part of smart cities [3]. Motorists take advantage of traditional parking systems to determine the available parking lots. However, most of these systems rely on the installation of stationary sensors in car park areas. This approach has several drawbacks and the most important of which is that the install or removal of sensors is an expensive and time consuming. Therefore, the proposed architecture can provide the motorists with real-time parking suggestions without the need to install sensors. Building non-IoT smart parking systems is important to facilitate the smooth transition from the existing conventional parking system infrastructure to digital transformation era which is basically equipped with sensors.

Currently, many traditional solutions for car parking such as Parking Guidance and Information (PGI) Systems [4 – 6], smart parking-based sensor [7 – 8], parking using IoT [3],[9 – 10] and block-chain technology [11–12] have been proposed in literature and most of these existed parking systems are based on sensors and IoT to identify the availability or unavailability of parking spaces. On the other hand, there are other methods that use ticketing machines in front of the parking areas, these mentioned methods are expensive in hardware and labor. In addition, theses infrastructure and car park systems are unable to support drivers to gain prior information about availability of car parks.

Additionally, a number of surveys [5], [13--14] and techniques [3 – 4], [7 – 12], [15], have focused on the car parking system problem, and, little attention was given to the process of obtaining the number of available parking spaces. Nevertheless, advancements of current technologies especially in information technology and mobile apps can be utilized to save time, cost and minimize efforts in smart cities. The aim of this paper is to develop an Informative Smart Parking System (ISPS) which allows people to have a prior knowledge about the car park spaces availability in real time basis. In this way, the motorist can decide either to go forward or change their target directions. Furthermore, a novel mathematical model will be used to calculate the number of available car parking spaces after calculating the expected arrival time based on real time information. Additionally, the proposed system can be used in shopping malls, hospitals, airports and anywhere parking system are available. Therefore, finding a vacant parking in congested cities has been considered a big challenge [15 – 16].

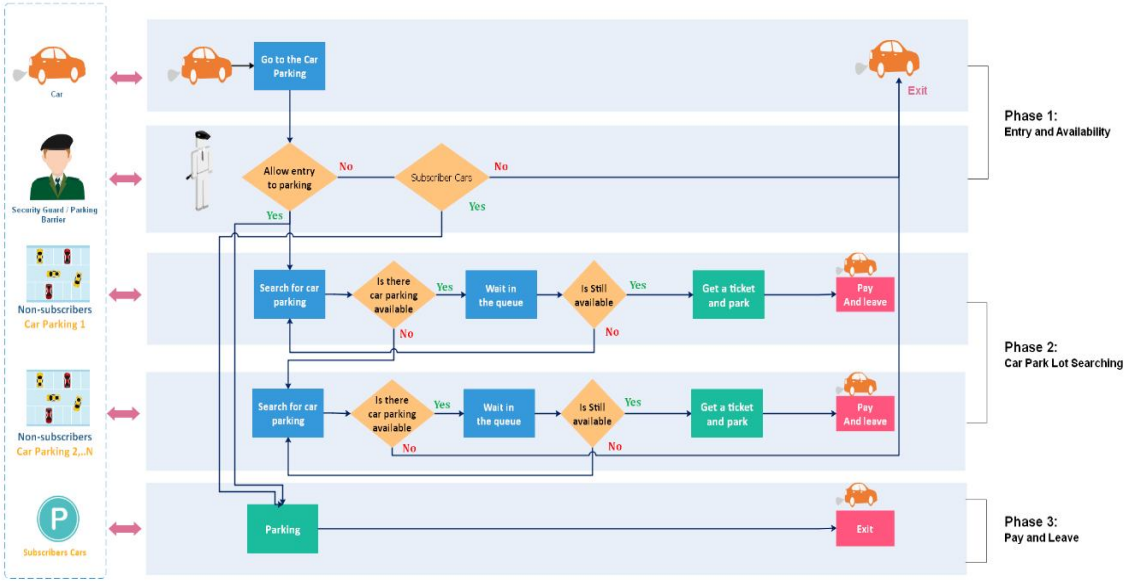

Figure. 1: Current architecture of conventional parking system

The rest of this paper is organized as follows: Section 2 presents the related works. Section 3 briefly introduces the current architecture of conventional parking system. The proposed Smart Architecture of Parking System is explained in section 4 and finally the conclusion is provided in section 5.

2. RELATED WORKS

Several studies have been conducted in an attempt to improve parking systems [4 – 5], [8 – 10] and [12 – 13]. These can be categorized into four different research approaches based on the technology used: parking guidance and information systems, smart parking-based sensor, parking using IoT, and block-chain technology.

In [4 – 6],[17 – 19] the authors have considered the development of PGI systems for various types of parking solutions. PGI systems provide motorists with guidance information through message boards installed at specific locations in roads to find vacant parking spaces. Basically, PGI systems use barriers and gates to count the number of vehicles entering and existing the controlled area. However, there are a set of obstacles associated with PGI systems, the most important of which is that these systems are unable to provide motorists with advance information about the availability of parking spaces.

While smart parking-based sensor model, [8] aims to minimize parking cost by using pricing strategy. This model considers the advantage of car lot reservations methods by motorist. However, this model considers a third-party authority as a compulsory payment process. In addition, a motorist does not receive any information regarding the parking availability. On the other hand, [11], provides a motorist information about the car parking availability as well as ability to reverse a car parking space as a prior process. However, the reservation of a parking space must be made 1 km distance away which is no reasonable since another person may be heading to the particular location faster than the motorist.

Moreover, some of these techniques concentrate on researchers focus on parking systems using internet of things (IoT). Smart cities become one of the modern cities characteristics with using IoT. The car parking is the major architecture component of such cities as developed in [3], [9], [13],[20]; however, these systems lack comprehensive informativeprocess, in addition to higher power consumption and maintenance cost.

A number of recent studies [11 – 12], [21 – 24] have reported that most of the existing smart parking systems are suffering from critical security and privacy concerns, which in turn has led to an increased interest in the use of block-chain security techniques. These block-chain techniques try to overcome the issues raised by the distributed denial of service (DDoS), attacks and single point failures, and driver's sensitive data privacy violation. These issues could result from managing reservation and payment process for different parking lots by centralized authority. However, block-chain implementations still suffer from traditional challenges, such as lack of poor infrastructure and other foundational technology issues that will require a broad coordination. The comparative study between the existing techniques and our (ISPS) proposed architecture is shown in Table 1 and explained in Section 4.

3. CURRENT ARCHITECTURE OF CONVENTIONAL PARKING SYSTEM

Figure. 1 presents a general view of the current architecture of conventional parking system. It consists of three phases, which are entry and availability, car park slot searching and pay and leave.

Phase 1: Entry and Availability

In this phase, motorists need to go to the target parking place. In the time of arrival to that place, security guard/parking barriers is responsible to permit the motorist to enter the parking place, the motorist is allowed to enter based the availability of a parking space. In the case of the motorist

has a monthly/yearly subscription, he/she is allowed entry to the parking lot if there is an available space, otherwise, the security guard/parking barriers will deny the motorist from entering.

Phase 2: Car Park Lot Searching

In this phase, motorist starts searching for an availableparking spot, if a spot is available then the motorist is required to wait in queue until his/her turn comes a ticket is issued and the motorist enters. In case the parking lot is full the motorist looks for another closer car parking.

Phase 3: Pay and Leave

This is the final phase in the conventionalparking system. When the motorist decides to leave the parking place, then the motorist is required to pay and leave the place.

Issues associated withthe currentarchitecture of conventional parking:

The main issues of *current* architecture of *conventional*parking system can be summarized as following:

1. *Wasting time in waiting process*

The motorists are spending long waiting time in queue which can be inside or outside the building parks. By the end, after a long time of waiting there may be no car parking available which leads to wasting time.

2. *Crowding in entrance or car park area*

In many events during peak times, almost daily, the entrance to parking areas are always crowed and could cause traffic jams depending on the location of the parking area.

3. *Environmental issues*

Vehicles idling and waiting in queue to enter or leave the parking areas cause environmental pollution.

4. *Unavailability Information of Parking Lots*

The most important factor required by motorist is knowing availability of car park lots.

Table 1: Comparative study between the existing techniques and ISPS

Feature / Approach	Applicable on conventional parking	Require additional hardware and sensors	Require third party to manage reservation and payment	Expensive and complex implementation	Provide current available parking spaces before movement	Update and notify motorists by Prediction of advance information during trip	Reference
(PGI)	No	Yes	Yes	Yes	Yes	No	[4], [5], [17]
Smart parking-based sensor	No	Yes	Yes	Yes	Yes	No	[7], [8]
Parking using IoT	No	Yes	Yes	Yes	Yes	No	[9], [20], [3]
Block-chain technology	No	Yes	Yes	Yes	Yes	No	[11], [12], [21]
ISPS	Yes	No	No	No	Yes	Yes	-

4. PROPOSED SMART ARCHITECTURE OF PARKING SYSTEM

The proposed architecture of parking system is called Informative Smart Parking System (ISPS) as shown in Fig. 2. In the *current* system of conventional car parking there are two types of people who use such system, these are subscribers and un-subscribers. ISPS is useful for un-subscriber motorist and consists of three phases these are: registration, availability of car parking, and map and route.

- **Phase 1: Registration Process**

In this phase, the advancements in technology has been utilized by developing a mobile app (ISPS). This app helps a motorist in saving time, money, and minimized efforts. So, the motorist needs to download and register via this app. Therefore, the system starts after signing in by requesting the personal details of motorist account.This account is belonging to the car diver forever and can be used at any time and any place. After registration, the user is able to obtain information about parking availability.

- **Phase 2: Availability of Car Parking**

In this phase, motorists are required to use the mobile apps. This is the main advantage of the proposed system. Here, the motorists can check the availability of parking spaces by getting information from the car parking database using web API. There will be two scenarios: the first scenario there are no available spaces; however, the system keeps updating automatically and in case a car leaves the parking lot the motorist would be notified on the app; in the second scenario which is proposed in this work, available parking spaces are shown on the app during the time of driving to the parking lot. However, in the second scenario the app will continue updating the motorist and provide other options in case that spot has been occupied by another motorist during his/her way to the selected parking lot as shown in table 2. This approach can be calculated by using a mathematical model as discussed in next section.

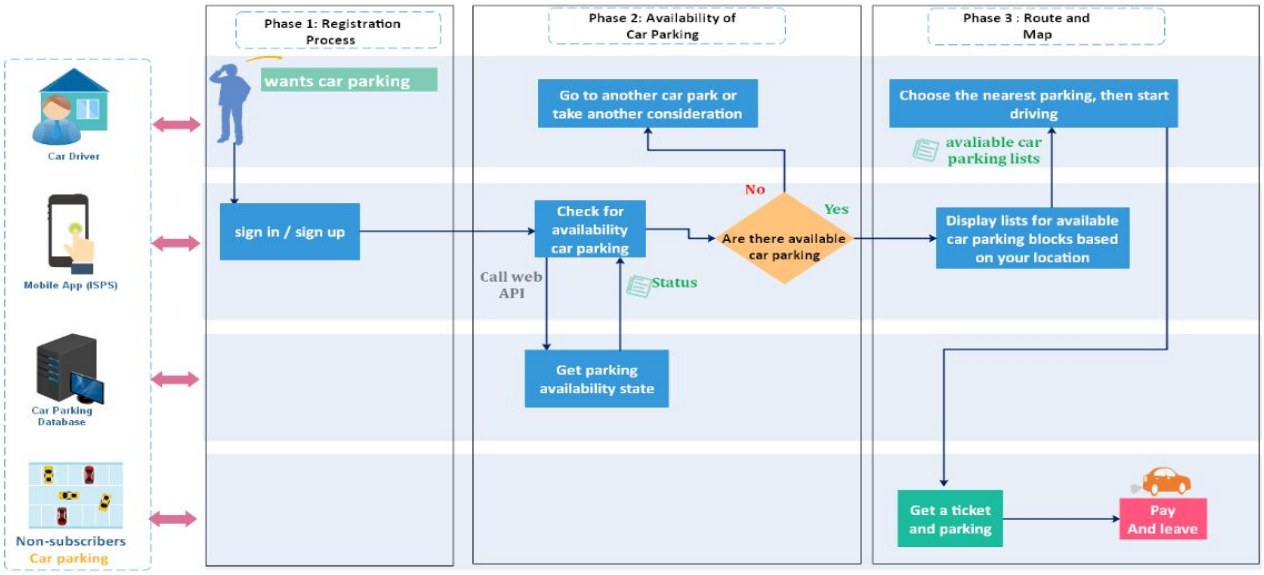

Figure 2: Proposed Architecture of Parking System

Table 2: Vehicles movement scenarios in predicting parking availability

Scenario No.	Motorist (i)	Start time = t	S_p^i	EA	$S_{entered}^{(t-5)}$	σ	$S_p^{(i+1)}$	Prediction status
1	Motorist (1)	t = 10:10 am	40	20	2	3	-3	Not available
	Motorist (1)	t = 10:20 am	50	10	2	3	27	Available
2	Motorist (2)	t = 11:00 am	50	27	1	3	20	Available
	Motorist (2)	t = 11:17 am	33	10	3	3	0	Not available

- **Phase 3: Route and Map**

In this phase, the car driver can start routing to destination place using Google Map which is integrated into the ISPS app. This is based on the availability and selected car park lot. By considering the time and distance between two points which are the source and destination using the proposed mathematical model as shown in (E1). This is to calculate the number of the available car parking spaces for each parking lot after expected arrival time:

$$S_p^{(i+1)} = S_p^{\,i} - \left[\left(EA \times S_{entered}^{(t-5)}\right) + \sigma\right] (E1)$$

$S_p^{(i+1)}$: refers to number of available parking spaces after expected arrival time

$S_p^{\,i}$: refers to the current number of the available parking spaces

P : refers to the parking lots(destination)

t : refers to the current time

EA : refers to trip's expected time from source to d

$S_{entered}^{(t-5)}$: the average number of vehicles parked in five minutes (using car park database)

σ : a constant value refers to the total number of vehicles in a waiting line for parking

prediction status if $S_p^{(i+1)}$ <= 0, then no available parking spaces

Else there is an available parking space

The main benefits of our proposed system are summarized in the following:

- Providing motorists with an advance information before and during vehicles' movement and taking early decision and consideration.
- Providing motorists with suggestions on available parking space and show them the nearest main port of car location.
- Reducing the traffic congestions at the controlled areas.
- Additionally, reducing traffic congestions and pollution in megacities and congested areas.

5. CONCLUSION

With the growing global number of vehicles on roads and consuming a long time in finding a vacant parking space, the traffic congestions and air pollution are inevitable. Thus, it is important to urge researchers to develop smart parking systems to be utilized by motorists and parking operators. Current issues associated with parking systems have been presented and discussed. In this paper, ISPS architecture has been developed to provide motorists with an advance information on parking lots availability. Moreover, we proposed and used a novel mathematical model to calculate the number of available parking lots considering the expected arrival time on a real time basis. This work contributes to driving the full digital transformation of smart cities.

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