Smart Parking Techniques Based on Internet of things

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ABSTRACT

Parking challenges have been a part of our community for a long time and old-fashioned parking management approaches have come a long way. The problems related with parking are common to all drivers. This paper tries to review globally implemented parking management systems that influence innovative technologies. Moreover, by testing a range of parking management solutions from around the world, this literature aims to test the shift in focus of modern parking management strategies. Finally, the paper does a simulation analysis of a case study for a big number of vehicles that are searching for a parking space. Furthermore, this paper gives a quick review about the most common parking techniques.

Keywords: Internet of Things, IoTs, Smart Parking, Wireless Sensor Networks, Large-Scale Simulation, RFID.

INTRODUCTION

The increase in car traffic in downtown is one of the effects of the recent rapid population growth in urban cities. In addition to the undesirable influence on the environment, the increase in city traffic has many other effects which as guessed, include the increasing request on parking infrastructures reachable to the public. Consequences, finding a free parking lot during rush hours is real trouble. Motorists keep cruising around wasting time and gas while expecting that a lot will be freed; this makes extra traffic delays and complication for other motorists. U.S Department of Transportation’s Federal Highway Association report that the number of owned motor vehicles has increased, more than twenty percent from 3,493,570 in 1994 to 4,224,542 in 2009 [1]. As a result, the number of vehicles will keep growing in the next years as well. One study states that about 70% of the world’s population will move, living in cities and nearby regions by 2050 [2]. Another study reveals that 30% of the congested traffic in the city is provided by cars that are seeking for free parking lots [3], so urgent smart parking solution is needed.

Parking management researchers are struggling to fulfill solutions that work towards a more efficient parking experience in order to identifying the need to resolve the above problems and satisfy demand for parking lots and better services. The parking availability is censored in real-time that technology opens up a chance for the provision of smart parking solutions that assist advance parking lot booking and dynamic pricing. By making such services available to the motorists, the operators suggest an improved level of service to their customers while at the same time increasing their revenues.

The Internet of Things (IoTs) is a new communication model that foresees a near future, in which the things of everyday life will be supplied with microcontrollers, transceivers for digital communication, and protocol stacks that will make them able to interact with each other and with the users, becoming an integral part of the Internet [4]. Intelligent transportation system (ITS) is one of the important application of the IoTs, it can efficiently solve several problems due to the increase of vehicle density by using the combination of sensor technology, RFID technology, network communication technology, information fusion technology, data mining and machine learning technology, network communication technology, automatic control technology, wireless positioning.
technology, image recognition technology, etc. Moreover, as a corepart of the intelligent transportation system, intelligent parking lot (IPL) can provide better user experience through the multi-sensor information fusion technology compare with the traditional parking lot [5].

In this paper term the latest developments in general parking infrastructures are presented. We are going to discuss the latest technologies around parking availability monitoring, parking reservation and dynamic pricing and see how they are utilized in different settings while highlighting the importance of mobile applications. This paper is organized as follows: parking detection techniques, smart phone based applications, survey on smart parking solutions, a simulation platform for large-scale parking events and finally conclusions.

**VEHICLE DETECTION TECHNIQUES**

**Sensors Technology**

Sensors are one of the important tools used in vehicle detection for parking system. Guru Prasad et al. (2012) employs Fiber Braggs Grating in-ground sensors for vehicle detection [6]. There are many other studies which use a group of sensors in detecting vehicle movement and parking space. Haoui et al (2008) at Sensys Networks Inc., uses a group of underground and overhead sensors in estimating parking occupancy [7]. This system consists of some in-ground sensor nodes, which use the Earth’s magnetic field to estimate a vehicle passing over them. For a combination of sensors, an overhead access point is also included in this vehicle detection system. Access point applies several algorithms to detect vehicle passing over the sensor after analyze the signals collected at its group of nodes. Basically, every parking space would have a sensor under it. Data from these access points is further added over larger network and used in determining characteristics of the system. Typically, these systems end up using a whole lot of sensors which makes the vehicle detection for parking more expensive. Caicedo did a research on systems (Parking Access and Revenue Control) takes an alternate approach at vehicle detection (Caicedo F.2009) [8]. Instead of using the sensors to sense every parking spot, this system uses them at key locations so as to divide the overall parking area into smaller zones and determines the parking occupancy over these zones. This doesn’t give an accurate result of information in the occupancy for each parking spot. However, it can be an alternative way to provide useful information at lesser costs.

**Cellphones based technologies**

As these technologies do not need any kind of physical infrastructure in order to function, they are the cheapest alternatives for parking. Lan et al uses in his research GPS, accelerometer and gyroscope sensors to detect the pattern of user’s movement in order to infer where they are walking or driving [9]. Moreover, it utilizes techniques such as map matching, which mainly checks if their movement is indoor or outdoor. By modeling the length of user’s steps with help of height and speed, their model determines the mode and path of user’s travel. A research Xu et al (2013) employs a similar approach in estimating the availability of parking spot [10]. They essentially use trained model to estimate the mode of travel and with help of patterns of mode changes, the parking spaces are estimated. However, these systems have some disadvantages, such as reliability of data, and the privacy concerns of making the GPS data available to a third party. There are certain non-intrusive cellphone based parking detection solutions like Roadify, as these are more focused on the crowd sourcing part of it that is a driver has to pick the choice that they have parked a car at a spot in order for the system to sense. However, depending on large number of drivers makes the reliability part of it more problematic as not everyone might select to report their parking status.

**Radio Frequency Identification Technology (RFID)**

Basically, these systems use RFID technologies to identify the parking lots available in the area. This is achieved by storing information about the id for the vehicle on a microchip with an antenna. RFID tag, as these are normally known as help identify the entering or leaving vehicles. Overhead scanners detect the information on these tags to record the parking status. Normally three types of RFIDs are used: 1) Active, 2) Passive and 3) semi-passive. Active tags powered with its own source and are considered to be better functioning. RFIDs better choice in practice as unlike barcodes multiple
RFIDs can be read at the same time, reducing the time of operation. However, due to their low price, passive tags are more common in parking management systems. Research study by Ganesan et al. (2007) after applying RFID to collect information about availability of parking, it is updated on the web servers continually for the help of drivers [11]. The Ganesan discuss an automated parking space allocation system by splitting this task into 4 modules, 1) Serial Port Communicator, 2) Free slot checker, 3) Parking charge calculator and 4) Free slot viewer. It provides a functionality where drivers can communicate with the system to get results in form of a text message and they will also be able to park a space with help of a specific text message.

**Image Recognition Technology**

Image recognition technology is a significant area of artificial intelligence (AI). Several mathematical techniques like fractal theory, fuzzy set, genetic algorithm, wavelet analysis have been utilized to image recognition effectively. In the smart parking space, image recognition technology is applied for parking lot detection, vehicle detection, license plate detection and for security as well.

**Network Communication Technology**

This technology concerns about transmission of sensor data, low data rate, low mobility, and etc. to fit obligation of IOT business. In the smart parking space, there are several categories of sensor interfaces include RS-232/485, CAN, Ethernet, WiFi, RFID, ZigBee, etc. Therefore it is necessary to propose an intelligent gateway to achieve lower-layer interface intercommunication and upper-layer protocol translation [5]. Since IPv4 is overwhelmed for sensors, IPv6 can take advance possible steps to allocate IPv6 address to every sensor.

**Wireless Positioning Technology**

Wireless positioning technology can be classified into two categories; indoor positioning, which mainly use GPS satellites, and outdoor positioning, which typically use RFID, ZeeBee ad hoc network and Wi-Fi network. Positioning techniques based on Received Signal Strength Indicator (RSSI), Time Of Arrival (TOA), Angle Of Arrival (AOA), Time Difference Of Arrival (TDOA), etc. Web and Smart Phone Apps with positioning and navigation service help intelligent parking system to locate vehicles accurately.

**Information Fusion Technology**

Information fusion is the combination of information from various sensors and databases in multiple modalities and located in several spatial and temporal domains. Information fusion includes Measurement Technique, Uncertainty Theory, Pattern Recognition, Decision-Making Theory, Optimization Theory, Estimation Theory, etc. In general, the points of information fusion are to: a) sense certain significant events, and b) confirm the consistency of sensed events. Research by Chang and Jungert proposed a novel approach for sensor-based query processing and query optimization using the sensor dependency tree [12]. Within intelligent parking space, this approach can increase efficiency and accuracy of detecting system, charging system, navigation system, positioning system, alarm system, etc. And then help to overcome parking challenges.

**SMART PHONE BASED APPLICATIONS**

In this section, exploring the current research in the smart phone based apps and also to certain existing parking management solutions. Grazioli et al reveals the extensive framework of having a smart phone based user interface for parking management systems. In this research they try to design a complete system containing of web apps for parking management team and web or smart phone based apps for users. Some of existing solution below:

**ParkingMate**

Smartphone based app. It shows the nearby parking rates and services. It does not give real-time information about availability of spaces.

**VoicePark**

This app has voice commands features. So, no need to look for the phone while searching about parking space.

**ParkMobile**

This phone based app let user to display and adjust the data on parking meters like add time on the meter.
SecureParking
This app gives real-time the availability of parking spaces and enables users to add time one those.

SFpark
This app was developed as a prototype in order to improve the parking utilization in San Francisco. The purpose not only displaying the available parking spaces or ability to pay online, but also enabling a dynamic pricing module to enhance parking utilization. More details in section 3.2.

Merge (Xerox)
Merge is an endeavor by Xerox to provide an integrated parking solution which can manage parking infrastructure, the revenue and people. It can provide real-time parking availability data to the drivers. Furthermore, it records this data to determine dynamic pricing of the parking spaces in order to manage the demand better and increase the revenue.

Cisco and Streetline
This project was settled between two big companies like Cisco and Streetline. The partnership used Cisco’s camera based with streetline’s sensor in order to gather data. As a part of this effort a City information System is also being suggested to grow the use of the system for other applications such as smart lighting, video surveillance etc.

Android, where is my car? (App Inventor)
This App developed at MIT. It allows the users to save the location of parking so that it would be easier for them to find their car easily. Use of this app comes to fore during big events where the parking is spread over large areas such as concerts or games. Essentially, this app will help in tracing back the location of the vehicle when users are visiting some new place for the first time and are not familiarized with the parking arrangements. It uses google maps to compute the path way between the current location and the saved location of the vehicle.

AVAILABLE PARKING SOLUTIONS

With the improvement of sensor technology, many big cities have been deploying various IoT devices in and around the cities for censoring. For example, the City of Melbourne IoT deployment in Australia [15], [14] and Smart Santander deployments in Spain [15]. Furthermore, wireless sensors have been installed in parking spaces, which record parking availability. Modern cities like San Francisco have made real-time parking information available to the public in order to help drivers make their decisions about parking. However, in order to professionally utilize these parking facilities and the real-time data, a high-tech mechanism is required as what many big companies proposed. This will help people to plan their trips ahead of time, and therefore save time and traffic congestion in finding available parking spots.

INRIX, Inc. and BMW automaker

Traffic Data Company INRIX and BMW revealed a predictive parking system at a connected car performance in Detroit June, 2015 that can assist drivers to find on-street parking spots [16], as seen in the Figure 1 scenario. According to the scenario, cars with intelligent sensors are connected to data center, when car (A) searching for vacant, Parking App will received information about free parking spot around from car (B) and then this information will send as a direction from data center to the mobile app for car (A). Parking availability prediction study is proposed, this study suggested an algorithm that can guarantee the confirmed parking vacant for drivers [17].

![Figure 1: BMW and INRIX parking scenario.](image-url)
BMW collaborate with INRIX to include the breakthrough services into its connected-drive cars. The services provide information with vacancy updated hourly, pricing rate, parking restrictions and policy rules. Moreover, these services show the availability of on-street and off-street parking, it compare Furthermore, distance and price then locate the nearest parking lot that fit driver’s needs.

INRIX is working with 100’s world-class companies and public institutions to change the way how people and commerce move through world transportation networks. As Big Data and the IoT changes whole thing where they do to how they get from place to another , INRIX is at the forefront of connecting cars to the cities and understanding science of intelligent traffic systems. INRIX control the most robust driver network in the world that has 250 million vehicles, smartphones, cameras, sensors and other incidents with the ability to cover nearly five million miles of road in more than 40 countries. The parking system for on-street parking include: 1) Real-time information. 2) Less reliance on roadside counters and costly sensors. 3) Better insight for urban planning. 4) Calibrate demand pricing models [18]. INRIX services existing in Seattle, Vancouver BC, San Francisco, Amsterdam, Cologne, and Copenhagen, by the end of 2015 the service will expand to 23 cities globally.

**SFpark parking management**

In 2013, San Francisco Municipal Transportation Agency (SFMTA) applied SFpark with deploying 8200 magnetometer sensors on-street in the pilot areas of San Francisco, a federally-funded demonstration of a new method to parking management that joined improved price and information about availability of parking, including real-time information from on-street and off-street parking, and demand-responsive rate modifications based on latest historical parking occupancy rates. SFpark works based on smart pricing and that lets drivers easily catch a free spot. SFpark continually adjusts meter and garage pricing up and down to match demand in order to help reach the right level of parking availability. Demand-responsive pricing encourages drivers to park in underused areas and garages, reducing demand in overused areas [19].

SFpark has many benefits [20]: 1) It reduces 43% of searching time for parking space, see Figure 2. 2) Greenhouse gas emissions 30% decreased, see Figure 3. 3) It is easier to pay and avoid citations. 4) It helped to reduce Peak period congestion. 5) 8% traffic volume is decreased. 6) 3% traffic speed is improved. 7) 30% Vehicle miles traveled is decreased, see Figure 4. 8) Double parking decreased when parking availability improved. 9) Transit speed improved where double parking decreased. 10) It slightly increases net parking revenue. 11) Improved availability supports economic vitality. 12) It makes streets safer because of reduced vehicle miles traveled and less distracted driving.
Cisco and Streetline Inc

Generally, in this solution which is the cooperation between Cisco and Streetline the concept is the same as the previous solution. However, The CSCCP (Cisco Smart+Connected™ City Parking) make it more secure and reliable by consisting the system a vision sensor like a camera. CSCCP provides drivers with real-time information about vacant parking lots. The result is less traffic congestion, less wasting time, less fuel consumption and a more effective business between cities, citizens, local businesses, and parking enforcement agencies [21].

A typical CSCCP solution comprises: 1) Cisco technical components (End-to-end network, Video end point Video infrastructure and analytic, Data center infrastructure, and Smart+Connected City Parking Software) 2) Streetline components (Parking sensors, Parking sensor gateway, ParkSight™ - policy management application, Guided Enforcement™ - application, and Parker™ by Streetline - citizen mobile guidance application). CSCCP facilities accessed via the Cisco Smart+Connected City Wi-Fi infrastructure, are at the heart of the solution. Streetline sensors detect the real-time availability of parking spots, while also integrating with digital meters to identify meter violations. Video cameras enabled with analytics monitor parking spots and no-parking zones. The system can also track specific vehicle types and report on loading zone violations. Streetline’s suite of applications for consumers, city officials, and enforcement officers ensure that the correct information is delivered, at the right time, to the right people for decisions. The significant part of the solution is intelligent parking services which accessed via Cisco WiFi infrastructure. The mission of detecting vacancy of parking lots in real-time assigned to Streetline sensors. Moreover, those sensors can identify meter violations and report loading zone violations.

Siemens and Intel

Siemens and Intel together are putting the foundations of a sensor and communication network for upcoming smart city models. Zwick and his colleagues have been working since October 2013 to develop new methodologies to the parking problem [22]. A sensor network, based on recently developed radar sensors installed overhead, always monitors the parking lot and reports the occupancy status to a parking control center.

This sensor is made up of an analog electronic system, an antenna, an analog to digital converter, and a signal processing part. The proposed solution system: 1) reports the occupancy of vehicle in real-time. 2) Sends information about the size and position of the vehicle. 3) Detects any barriers on bicycle, bus lanes and forecourt entrances caused by wrongly parked vehicles. 4) Measures traffic flow. 5) Optimizes autonomous vehicle navigation. 6) Notifies drivers of electric cars about charging station services. 7) Detects frequent parking space conditions at certain times and estimates predictions in order to give drivers an accurate forecasts they could see at their destination. The solution system and the software have capability of learning according to collected data and that's what makes it a special system.

A SIMULATION PLATFORM FOR LARGE-SCALE IOTS NODES FOR PARKING SCENARIOS

Working with a high number of devices, or deploying them in wide area, are challenging. Large-scale systems and applications, for deploying devices to target environments before being, is needed to handle the complexity of big network’s devices. Traditional IoTs simulators do not focus on the simulation of large scale deployments, as they are planned to evaluate and analyze low-level
networking aspects, with groups of smart objects arranged in particular topologies. Giacomo et al. [23] proposed methodology based on the view of IoT Node, as seen in the Figure 5 below, network models, and an energy model, which can cooperate to better characterize the behavior of simulated nodes. The mobility model describes location, movement, velocity, and acceleration change over time for IoT Node. Network models defines network abilities of each interface that IoT Node is supplied with. For instance, these models express delays and failure rates in the delivery of data in the network. Lastly, the energy model describes the activities of the IoT Node from an energy consumption and duty-cycling concept.

In addition, they proposed a case study, they decided to define several simulation scenarios calculated the required time to complete the simulation. One of that scenarios is to simulate smart parking infrastructure, sensor nodes are deployed to detect car presence. Moreover, gateways are collecting data from the sensor network. In particular, the vehicle’s requests to gateways are arranged by stochastic mathematical function a Homogeneous Poisson Process. When a vehicle sends a request, it joins geographically with the nearest gateway. Next, the gateway contacts the parking sensors and waits for a response. Afterward, it connects a response to the vehicle. All this occurs for a lifetime of the simulation equals to four hours. Figure 6 shows how simulation scenario works, where some vehicles cruising around a city, send messages with gateways using LTE communication standard and also presents wireless sensors networks which transmit their data to the gateways.

![Figure 5: visual model of an IoT Node](Image)

![Figure 6: Sample IoT (smart-parking) scenario for the simulations](Image)

All the members of this simulation are fulfilled by sub classing our implementation of the IoTNode class. In particular, those nodes termed by the VehicleNode, HubNode and SensorNode classes. Number of nodes has been varied in six cases as seen in Table 1 below, and simulations have been implemented on a server with the features of 16 GB RAM, 2 GHz Xeon CPU, and Ubuntu Linux OS.

**TABLE 1: NUMBER OF NODES OF EACH SIMULATION SCENARIO [23].**

<table>
<thead>
<tr>
<th></th>
<th>SensorNode</th>
<th>HubNode</th>
<th>VehicleNode</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4000</td>
<td>8</td>
<td>500</td>
</tr>
<tr>
<td>B</td>
<td>8000</td>
<td>16</td>
<td>1000</td>
</tr>
<tr>
<td>C</td>
<td>20000</td>
<td>40</td>
<td>2500</td>
</tr>
<tr>
<td>D</td>
<td>40000</td>
<td>80</td>
<td>5000</td>
</tr>
<tr>
<td>E</td>
<td>100000</td>
<td>200</td>
<td>12500</td>
</tr>
<tr>
<td>F</td>
<td>200000</td>
<td>400</td>
<td>25000</td>
</tr>
</tbody>
</table>

The number of scheduled events has been reported in Table 2. In particular, in this simulations a very accurate mobility model have been adopted and this requires the prevalence of mobility events rather than communication or birth events.
As the reader can see, the presented simulation platform SmartSantander testbed, which is one of the most famous real IoT platforms in urban cities, can easily manage a very high number of nodes and the associated events. As well this simulation platform is formed about three thousands IEEE 802.15.4 devices, two hundreds GPRS modules and two thousands joint RFID tag/QR code labels deployed both at static locations as well as on mobile vehicles. As seen in scenarios B and C the platform allows to simply simulate realistic scenarios in short time. Furthermore, even with the massive number of nodes as in scenario F, the calculation time is still adequate. The results of simulations in terms of execution time showed in Figure 7.

![Figure 7: Execution time with respect to the number of events, for six consider scenarios [23].](image)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Stores</th>
<th>Cars</th>
<th>Parking diversity</th>
<th>Events</th>
<th>Average Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5</td>
<td>100</td>
<td>3</td>
<td>+2000</td>
<td>4-6</td>
</tr>
<tr>
<td>B</td>
<td>5</td>
<td>100</td>
<td>4</td>
<td>+2000</td>
<td>0-40</td>
</tr>
<tr>
<td>C</td>
<td>5</td>
<td>100</td>
<td>6</td>
<td>+2000</td>
<td>0-10</td>
</tr>
<tr>
<td>D</td>
<td>5</td>
<td>100</td>
<td>8</td>
<td>+2000</td>
<td>0-2</td>
</tr>
<tr>
<td>F</td>
<td>5</td>
<td>100</td>
<td>10</td>
<td>+2000</td>
<td>5-10</td>
</tr>
</tbody>
</table>

**The influence of Intelligent Parking System and Land Use Diversity on cruising for curb parking.**

We did an experiment simulation about the effect of smart parking system and spot diversity on cruising for parking space. In this simulation result we used NetLogo simulator, a multi-agent programmable modeling environment, to study the impact of three parameters:

- Stores: The number of stores in the scenario.
- Cars: The number of cars in the scenario.
- Parking diversity: The diversity level of parking, represented by range of parking time assigned to parking spots.

The results written in the table 3 below, as seen we fix two parameters and change parking diversity in five cases with more than 2000 parking events. We come up with different average time for finding parking spots in five scenarios. We concluded, that the distance between stores and number of parking spots around stores are the main factors that increasing or decreasing time for searching parking spot. The closer stores from each other the less searching time needed to find a space. And also, the more parking spot around stores the less time cruising.

![Figure 9: Scenario A](image)

![Figure 10: Scenario B](image)
CONCLUSIONS

The resourcefulness of the advanced parking solutions allows enormous flexibility when fulfilling the various parking management solutions. There are a few ways the approach may be amended: 1) Developing hardware, which is cost-effective, would be a major improvement. Due to the current high investment, costs associated with real-time parking related hardware such as sensors, RFID chips, etc. are high 2) Reducing the costs linked with on-going maintenance would also help bring the cost down and therefore lead to wide acceptance 3) Researching ways to increase the system uptime and study parking trends more efficiently will help make this model better. The innovative parking solutions approach has a wide range of applications. This approach may be applied in many places like university parking lots, street parking, airport parking, commercial car parks, etc. Of course, minor alterations to the required hardware are needed but the core functionality remains the same. Many would benefit from the use of this approach, local governments, universities, medical Institutions and finally the public.

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