Exercise 1: IoT Based Smart Parking Solution

Sofeem Nasim, Aditya Mehta, Xinyi Yang
sofeem.nasim@oulu.fi, adityamehta@uni-koblenz.de, xiyang18@student.oulu.fi

05 April 2020

1 Introduction

With the emergence of technology and economic growth, transportation has become a certainly significant need in people's everyday lives. The recent increase in the growth of automotive industry coupled with urbanization has shown an increase in the number of vehicles. The population in Oulu in 2020 is approximately 200,000 [3]. As per European automobile manufacturers association survey in 2017, there are 547 cars per 1000 inhabitants in Finland [1], and this rate is increasing. Therefore, looking for a parking space has been a common need.

As per studies [5], implementation of technological solutions to assist users to reduce repeated glances help users to shorten the time to park the vehicle. Though a lot of researches have been conducted in this area, most of the existing parking management systems rarely address the issues of parking space management, vehicle guidance, parking lot reservation etc.[8]

The traditional parking spaces in the city of Oulu are maintained by existing vendors such as eParking[1], EasyPark[2], ParkMan[3] and eParkki[4] either independently or in collaboration with Oulun Pysäköinti Oy[5], owned by city of Oulu[6]. Recently, Kivisydän[7] parking space with the capacity of 900 places in the Oulu city centre was launched to facilitate parking needs of residents as well as of visitors of Oulu.

Although currently existing parking systems facilitate users to get information about the number of free spaces out of all available spaces at the display board, however, they do not provide navigation service to the nearest free parking spot. There are few mobile applications in operation by above-stated vendors in the city of Oulu, which offer facilities to make cashless payment by electronic cards or by mobile application and advance reservation. Such parking spaces are based on a pay-as-you-use

[1] https://www.eparking.fi/
[2] https://easypark.fi/fi
[3] https://parkman.fi/site/drivers
[4] https://electronicparking.fi/
[5] http://oulunpysakointi.fi/
[6] https://www.ouka.fi/oulu/english
[7] http://oulunpysakointi.fi/kivisydan/

model with charges as per the duration of parking.
As a representation, a message on display board in the traditional system is typically like shown in figure 1:

Figure 1: Traditional Parking Display

The existing solutions do not display the nearest free parking space from real-time parking data [6] and also there is a lack of providing navigational information seamlessly. Such issues can be solved by implementing smart parking solutions [8] based on IoT[4]. The users often have to keep looking on the street signs in the parking area to navigate to the free spot.

Our proposed idea of smart parking system is based on the IoT paradigm[4]. The system can provide real-time information about the parking space occupancy, which were not present in the aforementioned solutions. We aim to help users to ease the process of "looking for a free parking space" and save their time by providing navigational information for the nearby free parking space in the smartphone application.

2 Use Case

2.1 Target users and place of implementation

In general, our target users are the resident people in the city of Oulu looking for parking space, when they drive to their workplaces (company offices or university), to the city for their shopping needs, or to the airport for travel purposes. The solution can be implemented on the parking at the university, in the city centre, and at the airport. The decision of implementation can be taken after considering the overall cost of the system using the existing infrastructure and technology supporting this new implementation so that new purchases can be kept as minimal.

2.2 Users who will be benefited from the solution

Specifically, we divided potential users into three different groups and made different portfolios corresponding to their different customer journeys. Understanding customer journey is helpful for companies to do the customer experience design [7].

2.2.1 Portfolio 1

Jaakko is a master student in Engineering at the University of Oulu. Jaakko drives the car to the university for the lecture every day. However, he always struggles to park his car during peak hours.

The customer journey for users like him with the need to go to university is shown in figure 2. He gets up in the morning, gets ready to go, drives his car to the parking lot in front of the university, spends 10 minutes looking for a free space. Unfortunately, sometimes he gets late to the lecture because he is not able to find a free parking space. After the lecture, he takes a meal in Napa restaurant and drives home.

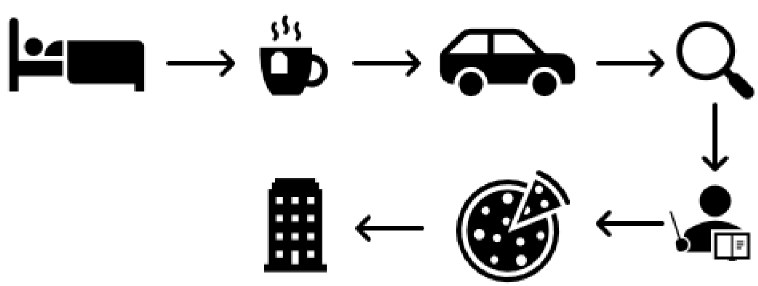

Figure 2: Jaakko's customer journey

2.2.2 Portfolio 2

Laura is white-collar personnel working in the downtown (Oulu). She is a punctual woman and drives to the company every day. However, as the number of citizens with a car is increasing, she realizes that she spends more time than before to find a free parking space.

The customer journey for users like her with the need to work is shown in figure 3. On a normal workday, she gets up, gets ready to go to the work as usual. She struggles to find a parking space close to her office. Therefore she considers taking the public bus sometimes because she wants to sleep for 10 more minutes in the morning. After the whole day's work. Laura goes to store Sokos to buy some ingredients for dinner and then go home.

Figure 3: Laura's customer journey

2.2.3 Portfolio 3

Juhot is a person, who likes to hang out for shopping, movie, restaurants, etc. during the weekend. However, he always complains that sometimes he spends 40 minutes in total go to the shopping mall and spend 20 minutes looking for a parking space.

The customer journey for users like him with the need to go to downtown is shown in figure 4. On a beautiful Sunday, he wants to hang out with his friends for shopping and a Sunday meal. He calls his friend after waking up in the morning. Then he drives his car to Sokos. However, he is not the only one who wants to hang out during the weekend, so he drives round and round for a free parking space. After the meal, he considers going somewhere else but afraid to face the same problem for parking, so he gives up the plan.

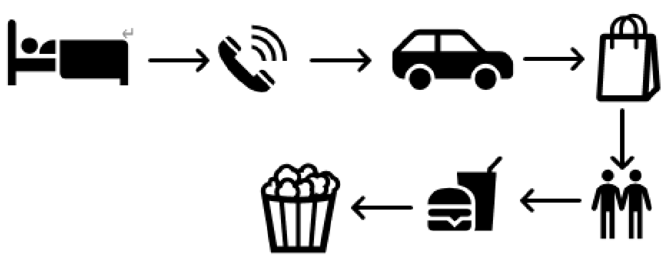

Figure 4: Juhot's customer journey

2.3 Operational methodology of solution

The operational methodology of this solution has been represented in the figure 5. Few icons used in figures are from Flaticon[8]. For instance, there are three parking spaces, out of which two are available. When the user comes, the available free

[8] https://www.flaticon.com/

parking space information is shown as on display screen in a traditional system. The navigational information for the nearest parking slot is displayed in the smartphone application of the user, using which the user can take their car to designated parking slot without any time wastage. As soon as the car gets parked in the slot, the sensor detects the vehicle and send this information to the LoRa gateway network, which sends it to a server on the internet. The display screen at the entrance gets updated according to this real-time occupancy information. When the next user arrives, similar steps take place and the user gets directional navigation to go to the third parking slot.

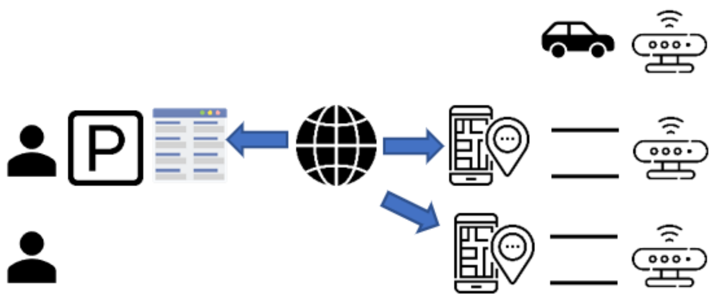

Figure 5: Customer use case

3 Methodology

The overall system design involves the implementation of the sensors. The PlacePod sensor devices were recently installed in electronic vehicle charging spaces in the city of Bodo, Norway. This installation helped the parking management team to ensure that the cars using the chargers are parked legally and based on the occupancy data of parking spaces, they were able to collect fines from illegally parked cars. [2]

The architecture of the proposed IoT system is shown in figure 6. As per our design idea, this consists of five main components.

1. PlacePod Sensors
2. BLE Device (for activating sensors)
3. Lora Gateways
4. Network Service Provider
5. Parking Application for end user

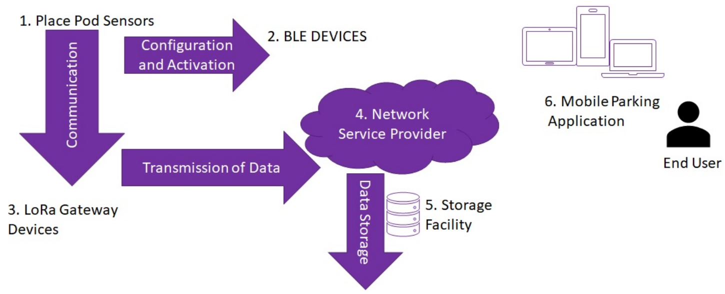

Figure 6: High level Architecture

3.1 Placepod Vehicle Detection Sensor

In our proposed solution, we will use the Placepod sensors. The functionality of the sensor is based on providing accurate, real-time vehicle detection and the location of available parking slots. It works on the magneto-inductive technology, equipped with RM3100 geomagnetic sensor and one of the high-performance magnetic sensors. Furthermore, its sensitivity is 30 times greater as compared to other magnetic sensors. Each sensor has a unique ID for easy provisioning, tracking and management. Currently, two types of sensor are utilized for vehicle detection, in-ground sensor in which the device is installed and mounted inside the surface. Likewise, the other type is a surface sensor, which is mount upon the surface without any drilling or digging effort. The choice of the sensor depends on the security level required in the designed parking area. Since the in-ground sensors are more secure as compared to the surface. However, the installation of in-ground sensor requires additional work of drilling and mounting.[2]

3.1.1 Installing and Mounting

Prior to installation, a preliminary survey of the site is required to test the feasibility of the sensor. In order to do the test, the following steps must be followed.

1. LoRa Network availability.
2. RF signal around -90dBm for better communication between the sensor and gateway.
3. Provision of PlacePod onto LoRa Network.

In order to get better accuracy, the sensor must be placed at the center of the parking slot as recommended by the manufacturer, with sensor positions displayed in figure 8

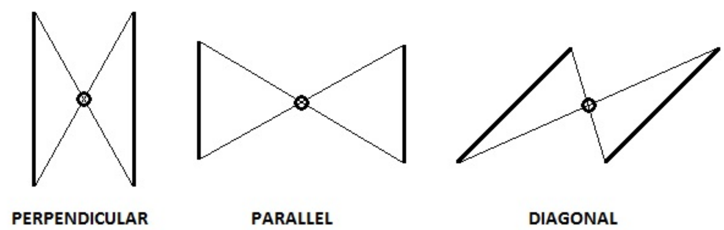

Figure 7: Alignment of sensor placement

3.1.2 Activation of the Placepod

For setting up the Placepod sensor, the first step is the configuration and activation of the sensors. It can be done by using Bluetooth devices and the android application provided by the sensor manufacturing company.

The android application consists of two core functionalities.

- Configuring
- Activation

The configuration functionality will perform the scanning procedure, in which it will list down the available Placepod sensors, whereas the activation function will activate the sensors, which in turn, enable the sensors to transmit the data on the network.

3.1.3 Communication Protocol

The placepod sensor works on the LoRAwan protocol to communicate with LoRa gateway devices. LoRa (low-power consumption, long-range technology) gateways are intermediate devices that allow sensing devices to transmit data to the network. This is a kind of intermediate hop between the sensors and network services, i.e. the internet. In our case, the PNI sensor follows the standard Cayenne Low Power Payload (LPP) Format. It provides a suitable way to send data over LPWAN networks. The uplink messages are highlighted in the table 1.

Table 1: Details of Uplink messages

Size	Field	Description
1	data channel	Parking Sensor Uplink Data Channel.
1	data type	Parking Sensor Uplink Data Type
N	data	Data

3.1.4 Communication and transmission

The PlacePod communicates with the gateway over several LoRa bandwidths 868 MHz (EU standard). The message is sent to the LoRa gateway by the sensor using the aforementioned bandwidth. The sensor transmits periodically, with default setting configured to 1 hour. However, keeping in view the European union regulation policies on data transmission, we plan to set the data uplink transmission to 1 minute.

3.2 Network Services

In our proposed solution, the network services from the third-party can be acquired. Since the LoRa gateway is not common in many areas. Generally, the devices or gateway supporting LoRaWAN are installed by private companies for commercial purposes. The thing networks are a globally well-known service provider for LoraWan technology and functional in the worldwide including Finland, as depicted in figure 8. Instead of deploying our own gateway devices, which can lead to problems such as coverage, device lifetime, power etc., we can acquire the already existing network services.

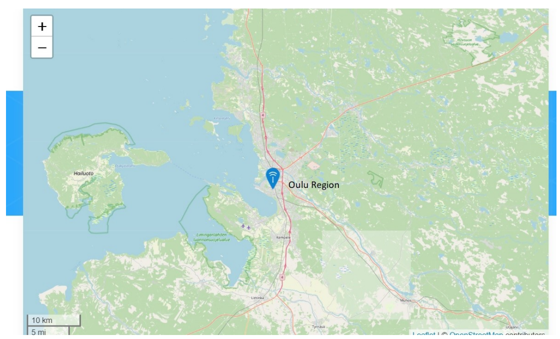

Figure 8: Thing Network Coverage

3.3 Data Acquisition and Processing

As per the preliminary survey of the size of the parking area, and the number of offered parking spaces, a number of sensors will be utilized. The sensors mounted at designated spaces detect the presence of the vehicles in real-time and such sensors communicate to the nearby LoRa gateway device to send the sensor data using LoRaWAN specification for wireless communication. A number of sensors are deployed in a specific distance range, and all of such sensors send their data to the mapped gateway device. It helps to estimate the number of gateways required and the number of sensors to be installed, along with considering the size and environment of the parking area. Thus, all the sensors are grouped or mapped to communicate with multiple gateway devices as per different communication ranges for data collection from sensors. The gateway devices collect the signals from various sensors and send this information to the network service.

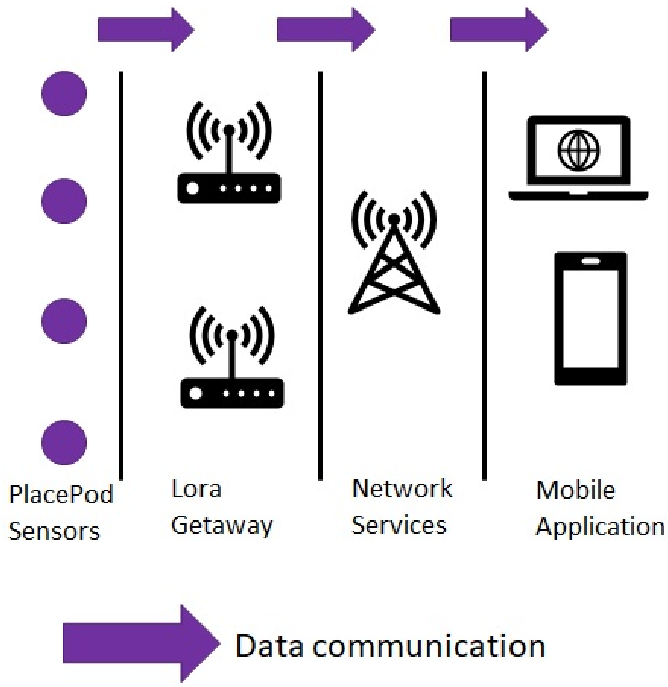

Figure 9: Data Communications

The data received to the network service can be routed through the internet to send it to the server. The server receives all these data and often it uses a designated local database to store this data. The API will be provided by the third-party for getting the data. A mobile application will be developed which will instruct or inform the user about the real-time parking situation. This workflow of data communication has been depicted in figure 9

3.4 Mobile Application

The smartphone mobile application will consist of a simple menu about the nearest free parking space and provides navigational service to enable the users to drive to the free space.

4 Conclusion

The proposed IoT-based smart parking system provides real-time vehicle detection that can aid the user to find out the free available parking space using the mobile application. In the traditional parking systems, the sensors used are usually not IoT based sensors. Also, the output from traditional sensors is the count of vehicles, whereas this is IoT based sensor and gives the output as the occupancy status of spaces. This information is utilized to send up-to-date information on a mobile application about free parking spaces in real-time and provides the navigation service to the user. In a future perspective, a methodology can be developed using data from the proposed platform that can provide a smart parking management prototype, which involves the perspectives of citizen views, local policies, businesses and environment impressions.

References

[1] European Automobile Manufacturers' Association. Vehicles per capita, by country. https://www.acea.be/statistics/tag/category/vehicles-per-capita-by-country.

[2] PNI Sensor Corp. Placepod vehicle detection sensor user manual. https://www.pnicorp.com/wp-content/uploads/PNI-PlacePod-Vehicle-Detection-Sensor-User-Manual-1.pdf.

[3] Statistics Finland. Businessoulu population. https://www.stat.fi/tup/seutunet/businessoulu_vaesto_en.html.

[4] Alex Grizhnevich. Iot for smart cities: Use cases and implementation strategies. https://www.scnsoft.com/blog/iot-for-smart-city-use-cases-approaches-outcomes.

[5] David G Kidd and Anne T McCartt. Differences in glance behavior between drivers using a rearview camera, parking sensor system, both technologies, or no technology during low-speed parking maneuvers. *Accident Analysis & Prevention*, 87:92–101, 2016.

[6] Sangwon Lee, Dukhee Yoon, and Amitabha Ghosh. Intelligent parking lot application using wireless sensor networks. In *2008 International Symposium on Collaborative Technologies and Systems*, pages 48–57. IEEE, 2008.

[7] Katherine N Lemon and Peter C Verhoef. Understanding customer experience throughout the customer journey. *Journal of Marketing*, 80(6):69–96, 2016.

[8] SV Srikanth, PJ Pramod, KP Dileep, S Tapas, Mahesh U Patil, et al. Design and implementation of a prototype smart parking (spark) system using wireless sensor networks. In *2009 International Conference on Advanced Information Networking and Applications Workshops*, pages 401–406. IEEE, 2009.