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# Implementation of 5G V2X services in Finnish private and public parking

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As the release 16 of 5G published, large-scale V2X commercial testing work is being conducted worldwide. telecommunication network has become the developing platform for cross-industrial business and various value-added service. The urbanization department of Helsinki is seeking solutions which solves crucial parking issues regarding existing dense transporting network and increasing population. Compared with 4G,5G network capabilities can enable advanced V2X applications and provide seamless V2X communications.

The purpose of the thesis work is to research the modeling work of communication system for dynamic parking session dispatching which can be applied to on-street or off-street parking scenarios.

The thesis introduced 5G and V2X capabilities and featured parking implementation system and designed communication model. The description of 5G framework and features are carried out in comparison with 4G, with its key communication technologies and challenges furtherly explained. Description of the V2X concept and the major applications together with potential models of parking communication session flow are presented in detail at the end.

| | |
|---|---|
| Keywords | 5G,4G,V2X |

## Contents

## List of Abbreviations

| | |
|---|---|
| 3GPP | 3rd Generation Partnership Project |
| 5G | Fifth generation |
| AMF | Access and Mobility Management Function |
| C-RAN | Cloud Radio Access Network |
| CUPS | Control-User Plane Separation |
| D2D | Device to Device |
| DSRC | Dedicated Short Range Communication |
| FaaS | Function as a service |
| IEEE | The Institute of Electrical and Electronics Engineers |
| IaaS | Infrastructure as a service |
| LTE | Long Term Evolution |
| MIMO | Multiple-Input Multiple-Output |
| MEC | Mobility edge computing |
| NEF | Network Exposure Function |
| PDU | Protocol Data Unit |
| QR code | Quick Response code |
| RAN | Radio Access Network |

| | |
|---|---|
| SMF | Session Management Function |
| WAVE | Wireless Access in Vehicular Environments |
| WLAN | Wireless Local Area Network |
| V2I | vehicle-to-infrastructure |
| V2N | vehicle-to-network |
| V2V | Vehicle-to-Vehicle |
| V2X | Vehicle-to-Everything |

# 1 Introduction

Parking is an important aspect of road traffic. It acts as an integral part of the whole transportation process. The difficulties of parking have always been a problem commonly faced by many cities all around the world due to the rapid growth of vehicles (especially for private cars). The issue is especially severe in the metropolitan area of larger cities where the development of urban economy has led to the growth of parking demand. However, the development of parking lot planning in many cities is relatively lagging, which is far from meeting the parking demand. Limited parking services will inevitably impact on local business, and lower the residents' life quality as well. It is reported that around more than 80 percent of people are dissatisfied with the parking arrangements in their cities. An increase in the construction can be another contributor to the parking problems in many residential areas. The large number of newly built high-rise buildings further decreases the space for parking.

A statistic reveals that, in Finland, the average number of motor vehicles owned by every 1000 people is 612, ranked the 14th in the world in 2014 (as shown in Figure 1), which means that every second person owns a car. With the high percentage of vehicle own-

ership in the Finland, parking has become a conflicting situation for lots of people. Nowadays, the increasingly serious problem of parking has become a major bottleneck for the implementation of automobile-related industrial policies and the guarantee of unimpeded urban road traffic.

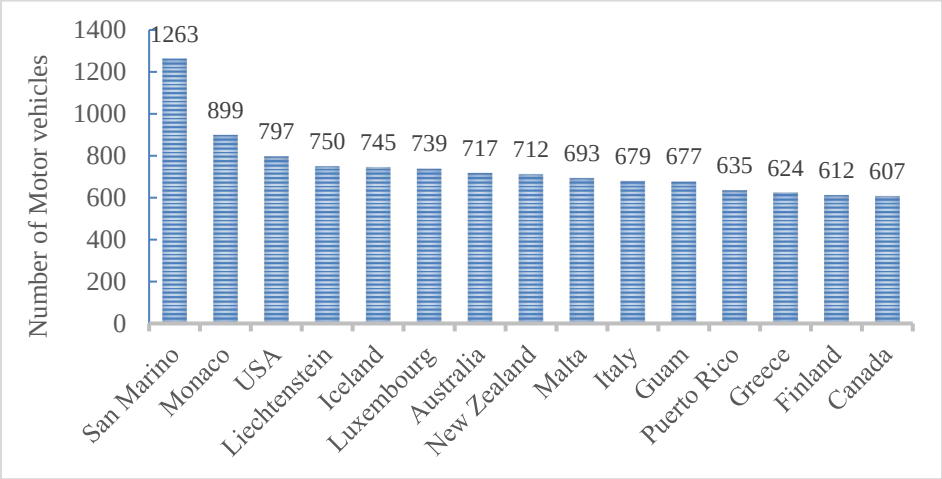


Figure 1. Motor vehicles per 1000 people in 2014 (Nationmaster, 2019)

In view of this, it is crucial and significant to develop suitable parking assist systems being able to quickly and accurately support the parking planning according to the parking demand information and parking facility layout, in order to accurately allocate limited parking resources in the city, improve the utilization rate of parking facilities as well as the service level of urban parking, and effectively alleviate the parking problem.

The rapid development of communication technology facilitates the increasing number of mobile users, along with the requirements for mobile communication. Nowadays, many countries around the world are paying close attention to the research of 5G communication technology in order to meet different requirements of users (Ibrahim and Abdullah, 2017). The evolution of mobile communication technology and its combination with V2X (vehicle to everything) services brings some new angles to deal with the parking problems.

The primary purpose of this research is to research the possibility of a parking space information sharing system based on V2X services, in which the parking space information nearby can be collected timely and distributed to the users who are searching for

available parking. In order to achieve the research aims, the objectives are addressed as follows:

- To understand the 5G communication technology.
- To understand the V2X services.
- To propose potential design of parking space-information sharing system based on C-V2X services.

The rest parts of the thesis are constructed as follows. Chapter 2 introduces the basic infrastructure of 5G and V2X services including their components, features, and key technologies. In Chapter 3, a parking space information sharing system design is presented and illustrated in terms of its working principles and modules used. The research result is concluded in the last chapter.

# 2 5G technology and V2X services

## 2.1 5G technology

A significant change of mobile wireless communication networks has been seen in the last few decades. Different generations (G) of the mobile wireless shows different features in terms of, for example, the nature of the system, latency, technology, speed, and frequency. The new features of a generation, as well as the techniques, standards, and different capacities, differentiate it from the previous one. 5G stands for 5th Generation and it has changed the ways of using cell phones within very high bandwidth. A comparison between the 4G and 5G with respect to some technologies can be found in Table 1.

Table 1. Comparison between 4G and 5G (Thirupathi and Angelinrosy, 2016).

| **Technology** | **4G** | **5G** |
|---|---|---|
| Start/Deployment | Now | Soon (probably by 2020) |
| Data Bandwidth | 200 Mbps | 1 Gbps |
| Technology | Wi-Max,<br>Wi-Fi, LTE | WWWW |
| Core Network | Internet | Internet |

| | | |
|---|---|---|
| Multiplexing | CDMA | FDMA |
| Primary Service | IP-based voice service | eMBB,mMTC,uRLLC |
| Key differentiator | Fast Broadband<br>, relatively low Latency | Large scale central to edge coverage, much lower latency, high realiabilty |

### 2.1.1 Architecture of 5G core network

According to the SA2 group of 3GPP, the 5G core network architecture can be depicted in Figure 2 (white paper, 2018).

Some key technologies are introduced to support the architecture of 5G core network such as the service-based architecture, network slicing, and control-user plane separation (CUPS). The application of CUPS aims to help the network user surfaces functions get rid of the "centralization", so that it can be deployed flexibly in the core network (central data centre) or in the access network (edge data center), finally realizing distributed deployment.

The control plane of a 5G core network can be divided into AMF and SMF, where AMF (single) is responsible for terminal mobility and access management, while SMF is responsible for dialog management functions. In the 5G core network, there are two types of reference points (which can be understood as the interaction between two specific functional blocks): one is the service interface-based which is represented using blue color; the other is traditional point-to-point communication-based which are presented in red color (Choi and Park, 2017).

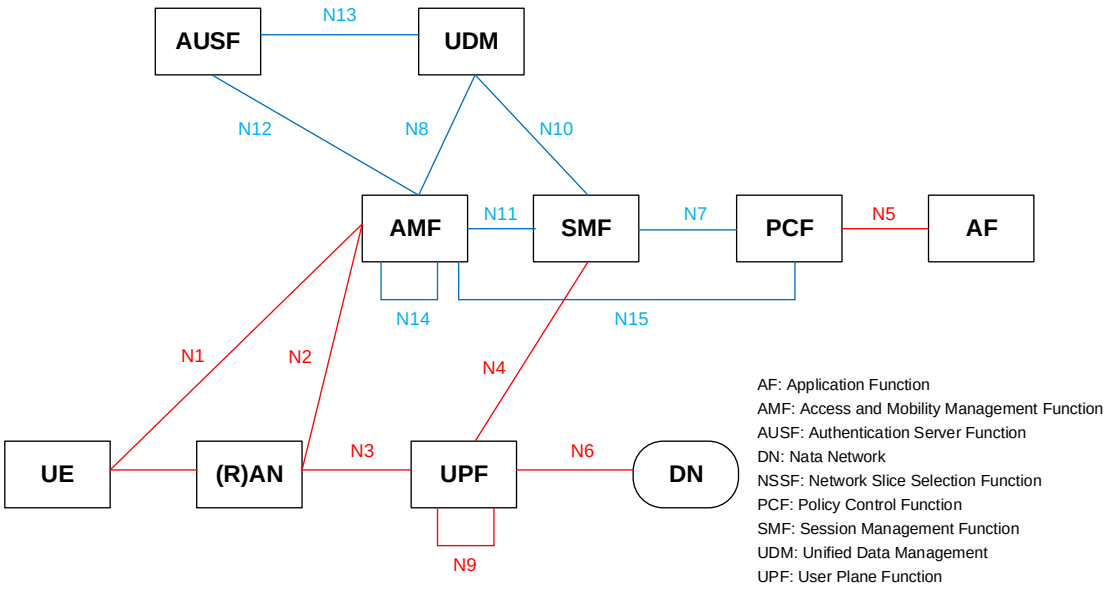


Figure 2. 5G Core Network Architecture (Developing solutions Inc., 2019)

In order to accelerate the 5G deployment and reduce the initial investment needed by operators, most operators will take a two-phase approach to deploying 5G. Non-Standalone (NSA) operation mode, which is also known as LTE-NR dual connectivity (DC), will be adopted initially, followed by standalone (SA) operation. There are several NSA options being worked on by 3GPP. In option 3, the 5G Radio Access Network's (RAN's) control plan is hosted by the LTE eNode-B (eNB). Figure 3 illustrates this type of deployment.

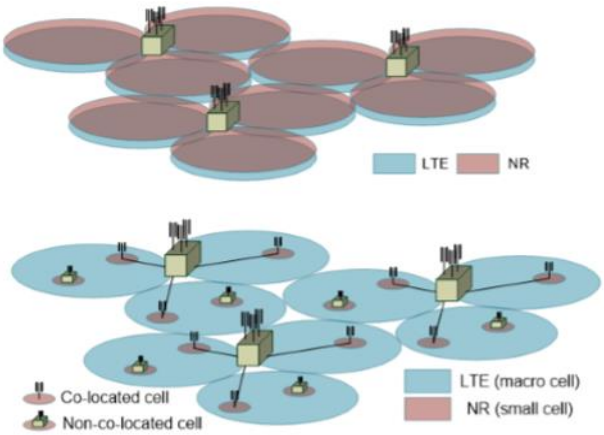


Figure 3. Cell layout where 5G NR and LTE coverage coexist (Techplayon, 2019)

### 2.1.2 Features of 5G mobile communication technology

Compared to the previous generations, 5G is more effective and attractive, which is usually connected with keywords such as high speed, high capacity, and faster data transmission. The main features of 5G can be concluded as follows (Vora, 2015).

(1) Good system performance

In the 5G mobile communication network environment, the number of communities, users, and antennas will increase greatly, and the application of 5G technology will focus on the coordinated network, connecting the community, users, and antennas. This will greatly enhance the performance of the system from different aspects. The traditional way of processing communication service work is conducted with more attention on indoor business, while the 5G mobile communication system works based on the indoor business, and continuously expand new business as well as the coverage area of the network, to realize the coverage of a comprehensive wireless network. The performance of 5G system is concluded in Table 2.

(2) Efficient spectrum utilization

High-band spectrum resources are significant in the application of 5G mobile communication technology. At the current stage, the utilization rate of high-frequency radio waves is relatively low and the penetration of radio waves is relatively weak, which limit its industrial application to a large extent. With the development of 5G mobile communication technology, the utilization rate of high-frequency radio waves can be effectively increased. Meanwhile, the combination of high-band spectrum utilization technology, wired/wireless broadband technologies, and optical-borne wireless networking technologies will further facilitate the development and application of 5G mobile communication technology.

(3) Low power consumption and cost

One of the key concerns during the research of mobile communication network technology is the reduction of power consumption and cost. With the research carrying on, more attention now has been shifted to the design of soft configuration. The operators continuously optimize the network resources by comprehensively analyzing the specific needs

of the market and the actual situation of business, so that the power consumption and cost of the system can be reduced.

Table 2. Expected performance of 5G system (Lopa, 2015).

| **Indicator** | **Performance** |
|---|---|
| Flow density | $10Tbit \cdot s^{-1}(km^2)^{-1}$ |
| Connection density | $1*10^7/km^2$ |
| Transmission delay | Air gap delay of 1ms |
| Mobility | 500 km/h |
| Network energy efficiency | 100 times improvement (compared with 4G) |
| User experience rate | 0.1-1Gbit/s |
| Spectral efficiency | 3 times improvement (compared with 4G) |
| Peak speed | 10 Gbit/s |

### 2.1.3 Key technologies of 5G

Some key technologies for 5G wireless communication networks are summarised as bellow (Wang et al., 2014).

(1) Multi-carrier technology

Multi-carrier technology can process radar signals and improve spectral efficiency. By setting the bandwidth between carriers, the carrier control can be fully utilized. In addition, it is also necessary to use a filter when transmitting information so as to make up for the limitations of wireless transmission technology. The insertion of the inserted prefix in the subcarrier enables the orthogonality between the subcarriers to be disconnected, which can reduce the interference of information and avoid the synchronization phenomenon of the subcarrier, thereby fully embodying the advantages of the multicarrier technology.

(2) Full duplex technology

Full duplex technology allows simultaneous two-way communication with signals of the same frequency. There are many types of self-interference factors in wireless communication systems. If two-way communication cannot be realized by the same frequency, a large amount of wireless resources will be wasted. The use of full-duplex technology can improve the spectrum utilization rate and make efficient use of resources for processing

signals, thus enhancing the use of mechanical equipment. In the industrial use of full-duplex technology, a staff needs to continuously reduce the self-interference of the signal and improve the power of transmitting and receiving signals. At the same time, it is necessary to effectively deal with resource allocation and networking.

(3) Device to device (D2D) technology

D2D communication can allow end users to communicate directly within a certain range by sharing cell resources under the control of the cellular system. The data traffic under this communication mode does not need to pass through the base station and the core network, which will reduce the communication delay by avoiding the external interference of the wireless communication data during the transmission process, reduce the base station pressure, alleviate the core network load, improve the spectrum utilization rate and system throughput, so as to increase the transmission rate, and reduce the transmission cost (Lu et al., 2018). Meanwhile, in order to give full play to the advantages of D2D technology, it is necessary to conduct research on the guarantee of real-time communication and the management of unlimited resource, which can promote the rapid development of 5G wireless communication network.

(4) Massive-MIMO

MIMO technology can optimize the multiplexing of communication bandwidth and transmit power so as to optimize the performance of wireless communication networks. With the continuous improvement of the technology level, MIMO has also been greatly improved, which can not only complete single-point to single-point operations, but also single-point to multi-point ones. In addition, the implementation of cloud wireless access network brings MIMO technology to the new systems so that the 5G performance can be further improved. MIMO technology holds many advantages, such as increasing the resolution of 5G communication systems, making full use of the resources of the spatial dimension, and achieving communication with the base station simultaneously, thereby effectively improving the application efficiency of the 5G mobile communication technology. Furthermore, the beams of the information transmission can be concentrated in a certain space to avoid the influence of external disturbance.

(5) Heterogeneous ultra-dense networks

5G mobile communication technology is developing towards the direction of diversification. With the development of human society, users' demand for data traffic is gradually increasing, and it is often the case that the mobile data volume exceeds the pre-set limit. The application of heterogeneous ultra-intensive network technology can solve such problems. It has a network-like density, but a wider coverage area. It is able to reduce the distance between nodes and endpoints, enhance the flexibility between the business side and the overlay layer, and allow more flexible network deployment and more efficient reuse of frequency, so as to improve the spectrum and power of the network. Although the heterogeneous ultra-dense network has the above-mentioned advantages, however, the increasingly dense network deployment makes the topological structure of the network more complicated, and inter-cell interference has become a major factor that restricts the growth of system capacity.

### 2.1.4 The challenges of 5G

Challenges are the inherent part of new development. Some big challenges that need to be dealt with by 5G are concluded as the following (Smail and Weijia, 2017).

(1) Global development imbalance of 5G technology

The development of countries varies in different regions of the world, and their demand on 5G technology is inconsistent. Thus, the considerations on the positioning and application scenarios of 5G technology are also different among various operators. For example, the United States expects a rapid development of 5G in order to solve the problem of home broadband access; Japan and South Korea aim to improve the Internet experience by using 5G technology; In China, although the fiber resources are rich, the population density is extremely high, and the population is concentrated in prosperous areas. Therefore, the current spectrum resources are difficult to fully support the demand of users, especially in holidays. The differences of regional demand will be a challenge for the development of the 5G industry.

(2) Integration of various standards

It is extremely challenging for the entire industry to reach a consensus on the development of unified global 5G standard, although different groups have already been involved

working on the standards around interoperability. Besides, the backward compatibility with precious technologies also plays an important role in the widely application of 5G in the future.

(3) Privacy and security

The protection of personal data is another issue that should not be ignored during the development of 5G. Different types of uncertainties related to security threats are on in front of 5G such as network hacking, system crash, and privacy, which are growing across the globe.

## 2.2 V2X technology

The Internet of Vehicles (IoV) is evolved with the increasing number of vehicles being connected to the Internet of Things (IoT). An IoV system is composed of three parts: vehicle terminal, cloud computing platform, and data analysis platform. The vehicle terminal is composed of a sensor, a data collector and a wireless transmitting module. It collects real-time running data of the vehicle, and realizes collection, storage and transmission of all working information and static and dynamic information of the vehicle. The real-time running conditions of the vehicle include the driver's operating behavior and the working data of the power system; the cloud computing platform processes the massive vehicle information, and filters the data. The data analysis platform is mainly responsible for reporting the data to managements.

By connecting people, vehicles, in-vehicle systems, and road infrastructure, IoV allows seamless links among inter-vehicle networks, and provides intelligent management and information services in the mobile environment, which will improve driving experience, traffic efficiency and safety, as well as reduce operational costs.

In recent years, with the development of communication technology, another concept that has gradually developed is vehicle-to-everything (V2X). V2X indicates the technology capable to facilitate vehicles to communicate with moving parts of the traffic system around them, which contains several components including vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-pedestrian (V2P), vehicle-to-network (V2N) and

others. V2V refers to the communication between vehicles through an in-vehicle terminal. The vehicle terminal can obtain information such as the speed, location and driving situation of the surrounding vehicles in real time, and the vehicles can also form an interactive platform to exchange text, pictures and videos in real time. V2V communication is mainly used to avoid traffic accidents, provide vehicle supervision and management. V2I means that the in-vehicle equipment communicates with the roadside infrastructure, and the roadside infrastructure can also obtain information from vehicles in nearby areas and publish various real-time information. V2I communication is mainly applied to real-time information services, vehicle monitoring management, and non-stop charging. V2P refers to traffic group (including pedestrians, cyclists, etc.) using user equipment (such as mobile phones and laptops) to communicate with in-vehicle devices. V2N means that the in-vehicle device is connected to the cloud platform through the access network/core network, and the data interaction between the cloud platform and the vehicle is performed, and the acquired data is stored and processed to provide various application services required by the vehicle. V2N communication is mainly used in vehicle navigation, vehicle remote monitoring, emergency rescue, and information entertainment services.

According to the usage of different underlying technologies, two types of V2X communication technology have been proposed, which are WLAN-based and cellular-based V2X.

### 2.2.1 DSRC

The original V2X communication uses WLAN technology and works directly between V2V and V2I. This type of V2X is based on standard which is called dedicated short-range communications (DSRC). DSRC utilizes IEEE 802.11p to add wireless access in vehicular environments. It permits low-latency communication of basic safety messages between vehicles and between vehicles and roadside infrastructure (Hu et al., 2017). The top-level protocol stack of the DSRC is developed based on the IEEE 1609 standard. The V2V information interaction uses the WAVE Short Message Protocol instead of the TCP/IP protocol used by WIFI. The TCP/IP protocol is used for V2I and V2N information interaction.

### 2.2.2 C-V2X

C-V2X is initially defined from LTE in 3GPP Release 14 and is designed to apply in V2I and V2N. In 3GPP Release 15, the V2X functionalities are expanded to support 5G. Like 802.11p, C-V2X direct communications support wide area coverage connections, enhanced safety awareness by detecting and exchanging information using high qualified transmission in the 5.9-GHz ITS band.

With the full range of connections and efficient information interaction between people, cars, roads, and cloud platforms, C-V2X is currently evolving from information service applications to traffic safety and efficiency applications, and will gradually support autopilot collaboration. Some typical application scenarios of the C-V2X include (Zhao, 2018):

- Traffic efficiency

Traffic efficiency is another important application scenario for C-V2X. It is of great significance to alleviate urban traffic congestion, energy conservation and emission reduction. Typical traffic efficiency application is speed guidance. Vehicle speed guidance refers to the collection of time information of traffic lights and signal lights by using roadside unit (RSU), and broadcast of the information such as the current state of the signal light and the remaining time of the current state to surrounding vehicles. After receiving the information, the vehicle calculates the recommended driving speed based on the current speed, position and other information, and prompts the vehicle owner to ensure that the vehicle does not stop passing through the intersection. This scenario requires that the RSU have the ability to collect traffic signal information and broadcast V2X messages to the vehicles, while the surrounding vehicles have the ability to send and receive V2X messages.

- Traffic safety

Traffic safety is one of the most important application scenarios of C-V2X. It is of great significance to avoid traffic accidents and reduce the loss of life and property caused by accidents. Typical traffic safety application scenario is collision warnings at intersection. Collision warning means that at the intersection, when the vehicle detects a collision risk of a vehicle traveling laterally, the driver is alerted by an early warning sound or image

to avoid collision. Vehicles in this scenario need to be able to broadcast and receive V2X messages.

- Information services

Information service is an important application in terms of the improvement of the driving experience. Typical information service application scenarios include emergency call services. Emergency call service means that when an emergency situation of a vehicle occurs (such as airbag detonation and rollover), the vehicle can automatically or manually initiate emergency rescue signals through the network, and provide basic data information, including vehicle type, traffic accident time and location. The service provider can be a government emergency rescue center, an operator emergency rescue center, or a third-party emergency rescue center. This scenario requires the vehicle to have C-V2X communication capabilities and can establish communication with the network.

- Autonomous driving

Similar to existing camera video recognition, millimeter wave radar, and laser radar, V2X is another method for obtaining information of other vehicles and pedestrian motion states (speed, brake, lane change), and it is not susceptible to influencing factors such as weather, obstacles, and distance. Meanwhile, V2X also helps to build a comprehensive service system for sharing the time-sharing and car-passenger cloud collaboration for the industrialization of autonomous driving. Currently, typical autonomous driving scenarios include vehicle platooning and remote driving. The platooning of vehicles means that the first vehicle is a manned vehicle or an autonomous self-driving vehicle. The following vehicles maintain real-time information interaction with the head vehicle through V2X communication, and realize a multi-vehicle follow-up driving with a certain car spacing at a certain speed. It has the functions such as lane keeping and tracking, collaborative adaptive cruising, collaborative emergency braking, and collaborative lane change reminders. Remote driving means that the driver remotely operates the vehicle through the driving console. The cameras and radars mounted on the vehicle will transmit the multi-channel sensing information to the remote driving console in real time through the large bandwidth of the 5G network; the driver's control signals for the steering wheel, throttle and brake of the vehicle will be transmitted to the vehicle through the reliable and low delay 5G network (Sahin et al., 2018).

Fifth generation (5G) technology will play an important role in the C-V2X by improving the reliability for vehicles to communicate with the road environment, and enabling the development of multiple revolutionary services.

# 3 Application of C-V2X services for assisting private and public parking

## 3.1 Parking problems in Finland

During the construction of many residential buildings, there is no adequate consideration of the parking demand around the building, which results in insufficient parking spaces. Besides, the situation that the parking space information is not conveniently available leads to the waste of resources. The current problems remain during the usage of parking spaces are reflected in the following aspects.

- Unreasonable roadside parking capacity

When a city road is constructed with parking spaces, the ratio of the number of parking spaces on both sides of the road comparing to road capacity should be between 20% and 33%. However, in Finland, the proportion of parking spaces on both sides is beyond the range. This has caused the unreasonable distribution of parking spaces on both sides of the road and public parking lots, which inevitably increases the traffic volume of the city,

- Parking allocation

Large public parking spaces are usually built around the city's core business districts such as hospitals, shopping malls, plazas, and schools. The traffic volume in these location is relatively high, and the situation that many vehicles are cruising to find place to park when all the parking spaces are occupied will make the traffic condition even worse, which will increase traffic congestion. The reasonable distribution of the parking lot has a great impact on mitigating traffic pressure. Therefore, during the selection and planning of parking locations, it is not suitable to only take the traffic flow into consideration with other factors being ignored.

- Parking spot utilization ratio

Two main factors that are considered by drivers when selecting a parking space are the distance to the parking lot and parking cost. Most car owners will try to park at the nearest place in order to save time. However, if they are not familiar with the layout of the nearby

parking lots, more time will be spent on selecting suitable parking spaces. This will result in the congestion of some public parking lots while some parking lots in the far area are underutilized. Besides, private parking spaces are mostly idle during the working time, while the parking space near the office buildings is in short supply, resulting in low utilization of private parking spaces.

- Parking spot searching

It is also time consuming to find a suitable parking spot within the parking area. Cruising for parking spot takes up to 30% of time in our daily driving activities

In view of the above-mentioned problems, this study proposes a framework for parking space information sharing by incorporating the technologies of C-V2X in order to resolve the parking problems, guide the private and public parking, and provide useful reference for the construction of intelligent transportation systems.

## 3.2 Design of parking service model

According to the current situation of the Finnish parking spaces, the parking spaces that can be shared are mainly private and public parking spaces (roadside parking spots and parking lots). By analyzing the parking spaces from the perspective of resource sharing, two types of sharing modes can be considered which are space sharing and time sharing.

- Available spot info sharing

To alleviate traffic congestion, it is necessary to reduce the number of vehicles that are searching for a parking space, which will help to reduce the traffic flow. This can be achieved by sharing the information of available parking spaces among the nearby buildings.

- Time sharing

For a certain parking space, it is impossible to be occupied all the time. Therefore, different vehicles can take turns using the parking spaces at different time periods. The

information of the free time of the parking spaces can be distributed to other drivers in order to achieve full utilization of resources.

### 3.2.1 Framework for parking service model

Through the analysis of the existing parking space information sharing system, the main goal of the system is to enable the drivers to find the required parking spaces through the parking space information shared on the platform, as shown in Figure 4. The parking space information sharing system designed in this work will be introduced from three aspects, which are drivers, shared-parking space, and parking space information sharing platform, as shown in Figure 5.

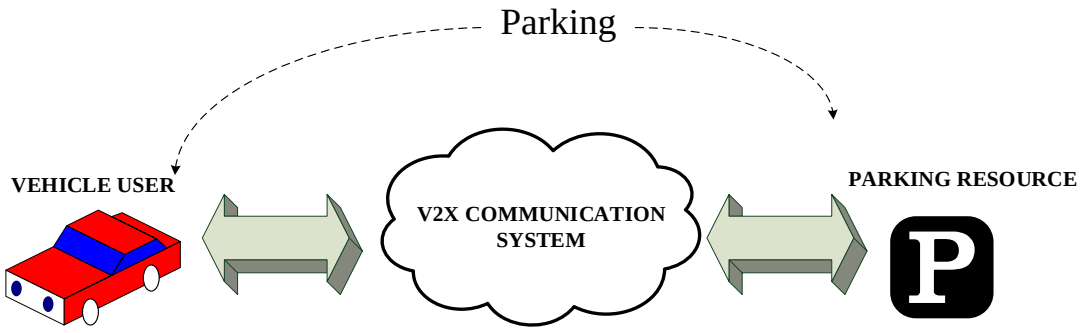


Figure 4. Schematic of parking service model.

The parking space searchers mainly include vehicle equipment, parking resource mainly including roadside equipment, and V2X communication syste includes communication protocols, dedicated datalinks, and manager systems. The communication protocol and the dedicated communication link include the short-distance communication between the V2X communication system and the parking space searchers; the manager system is used to check the authenticity of the information of the shared parking space, and the information can be sent to the parking space searchers.

During the process of parking a vehicle, the first thing that need to be considered is the access of vehicles. The qualified parking space information sharing system should not adversely affect the management system of the third-party manager in the area where the parking space is located, which means that in the practical application of parking space information sharing system, advanced vehicle access technology is required to

ensure the operation of the existing management system. There are many possible solutions under the existing v2x technology, such as,

(1) Quick Response code (QR code).

After the parking space searchers succeeds in booking a parking space, the sharing platform can determine the owner's identity by scanning the QR code sent by management systems.

(2) Car number recognition.

With the car number recognition technology, the parking space information sharing platform can transmit the car number recognition information of successful predetermined vehicles to the system of the parking space manager. Through the car number recognition, the parking space searchers can enter more conveniently, and it is also conducive to the management of third-party managers.

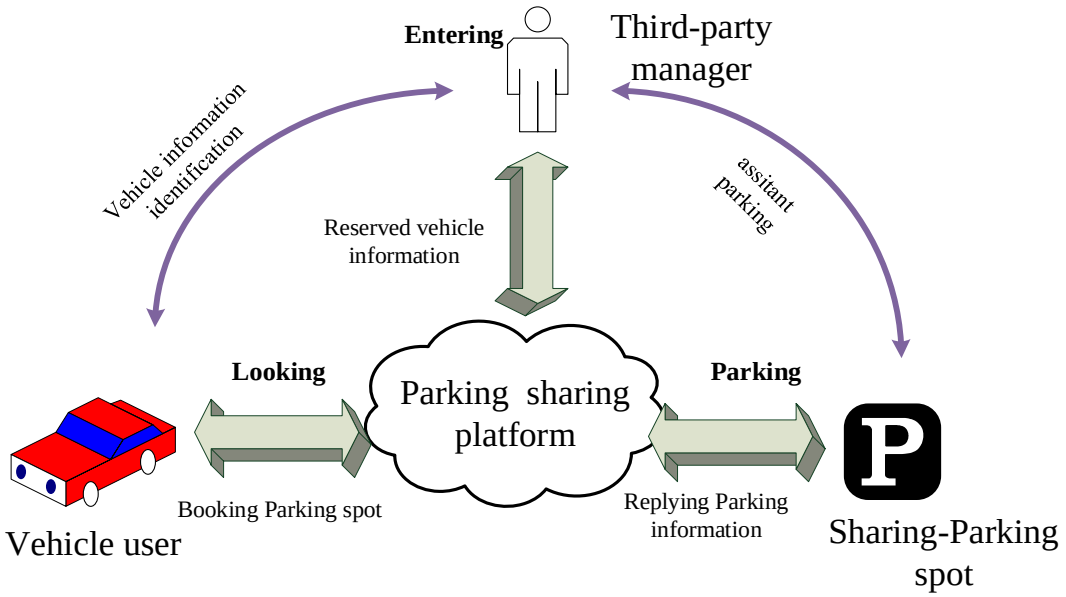


Figure 5. Schematic of parking system.

- Parking space searchers-vehicle user

It mainly contains vehicle equipment including wireless transceiver module, computer processing module and display output module. Its' primary purpose to receive nearby

parking space information in real time based on its own location. The utility model is configured to receive the parking space information transmitted by the communication module, process the parking space information, and convert the processing result into prompt information, such as sound and light signal that the driver can understand. In addition, navigation guidance can be provided based on the relative position containing the GPS location, information of the vehicle and the available space.

- Parking resource

The parking space search system mainly performs real-time statistics and analysis on the use of private parking spaces and public parking spaces. In the parking system, parking space searching is the interaction between the parking space searchers and the parking space information sharing platform. The shared parking spaces mainly include private parking spaces and public parking spaces.

For public parking spaces, the parking space information is detected, and the information is sent to the parking space sharing platform in time. The roadside sensor includes a camera and a laser radar, where the camera is configured to collect a video image of the road segment, identify an object type, shape, and position information in the video image, and transmit the information to the roadside processing unit; the laser radar is used for detecting obstacle information, transforming the information into a laser point cloud, and transmitting it to the roadside processing unit. As shown in Figure 6.

For the sharing of private parking spaces, the core resources are private parking spaces, which can be shared according to statistical methods and private parking spaces. One main problem in realizing the sharing of private parking spaces is to ensure the accuracy of the parking space information (Kong et al., 2018). During the process of the parking space sharing, the shared parking spaces must be approved by the private parking side before sending in order to avoid false or malicious information.

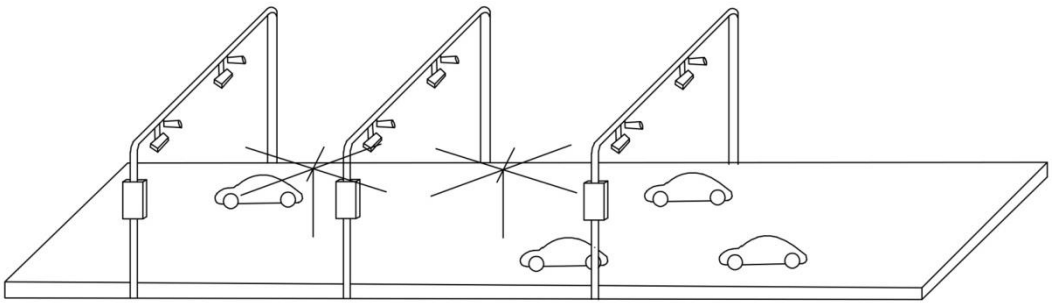

Figure 6. Arrangement of roadside sensors

- Communication entities

According to the analysis in Section 2, C-V2X is a communication technology based on 3GPP global unified standard, including LTE-V2X and 5G-V2X. From the perspective of technology evolution, LTE-V2X supports smooth evolution to 5G-V2X. C-V2X can be divided into V2X-Direct and V2X-Cellular communication modes according to different interfaces. V2X-Direct adopts the special frequency band of the car network (e.g. 5.9GHz) through PC5 interface to realize direct communication of V2V, V2I and V2P. The low delay and the support of high moving speed satisfy the requirements of decision and broadcast of parking space information. V2X-cellular is forwarded through the Uu interface of the cellular network, using the cellular frequency band (e.g. 1.8 GHz), and the downlink is broadcast. The two communication modes of C-V2X communication are independent and complementary to each other. A design of PC5 and LTE-Uu-based V2X parking space information sharing communication framework is shown in Figure 7 (Americas White Paper, 2018).

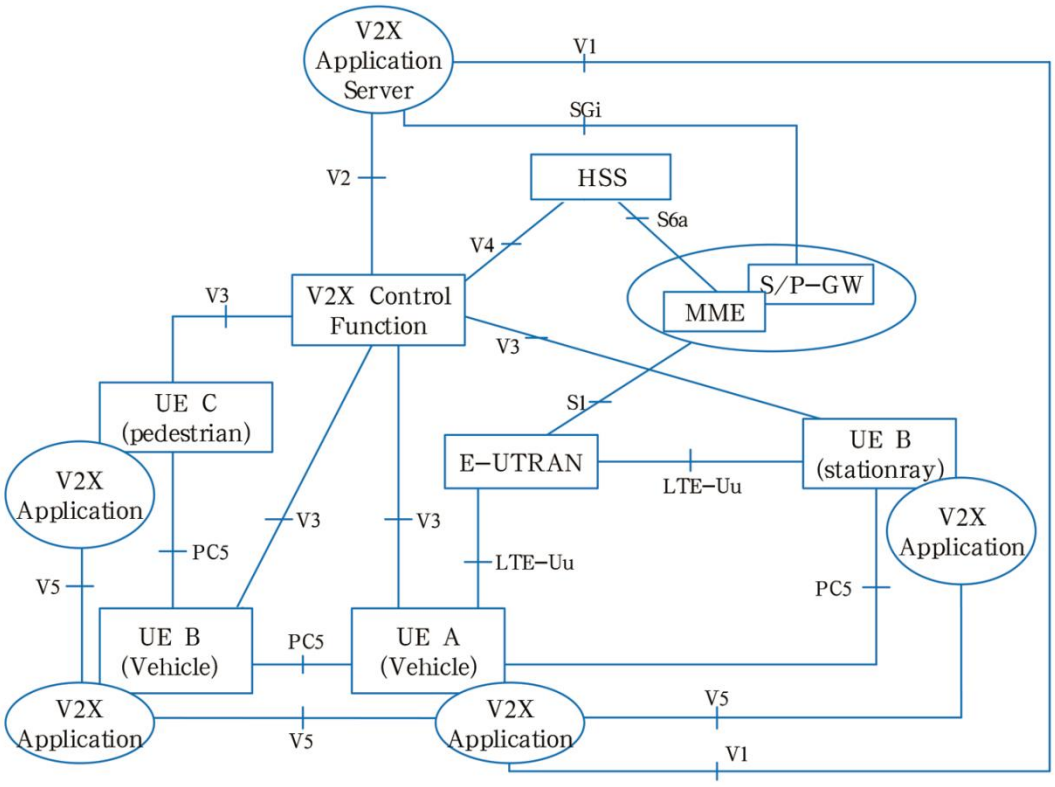


Figure 7. Model of PC5 and LTE-Uu-based V2X parking space information sharing communication framework (Americas White Paper, 2018)

RSU is an important infrastructure resource of V2X. According to the communication modes of LTE-PC5 and LTE-Uu. RSU deployment can be divided into the following two types. When the RSU receives a V2X message through the PC5 interface, the RSU is deployed as a logical combination of the UE and the V2X application, which called the UE-type RSU. When the RSU receives the V2X message through the LTE-Uu interface the RSU will include the eNodeB, and the built-in L-GW and the V2X application server, which is called the eNodeB-type RSU.

In this work, V2X communication is conducted based on PC5 and LTE-Uu simultaneously. Under this scenario, the UE communicates with other UEs (including the UE-type RSU) via the PC 5 for the transmission and reception of V2X messages. The UE-type RSU can communicate with the V2X application server in the mobile network through LTE-Uu and can be used to manage communication of V2X messages beyond the direct PC5 communication range as needed. In this situation, a hybrid communication method based on PC5 and LTE-Uu V2X is used, and there is no need to deploy the MBMS broadcast service on the downlink.

The RSU provides adequate coverage for the vehicle's transportation infrastructure. The UE-type RSU can communicate with the V2X application server and it receives the V2X message from other UEs through the PC5, in which the V2X application deployed in the RSU decides whether the message needs to be routed to the V2X application server through the LTEUu connection, for example, when the target area is larger than the V2X communication range on the PC5. The V2X application server can coordinate and communicate with other V2X application servers to determine the distribution of target areas and V2X messages (Wang et al., 2017). The V2X application server sends the downlink V2X message to the RSU in the target allocation area through LTE-Uu. The RSU broadcasts the received V2X message through the PC5 using V2X communication. The UE in the parking space sharing area receives the V2X message broadcast by the RSU through the PC 5.

For example, the parking space demander UE only needs to operate in the operating mode of the V2V/V2P service through the PC5. Only a UE implemented as an RSU can simultaneously perform a mixed mode of V2X communication through PC5 and LTE-Uu. This combination of PC5 based and LTE-Uu based V2X communication is also useful in use cases where the parking space subscriber may not be able to receive V2X messages directly from the remote UE via PC5. In addition, UE-type RSUs can use SIPTO connections to communicate with local V2X servers for latency-reduction goals. A PC5 and LTE-Uu-based mixed V2X communication scenario can be found in Figure 8.

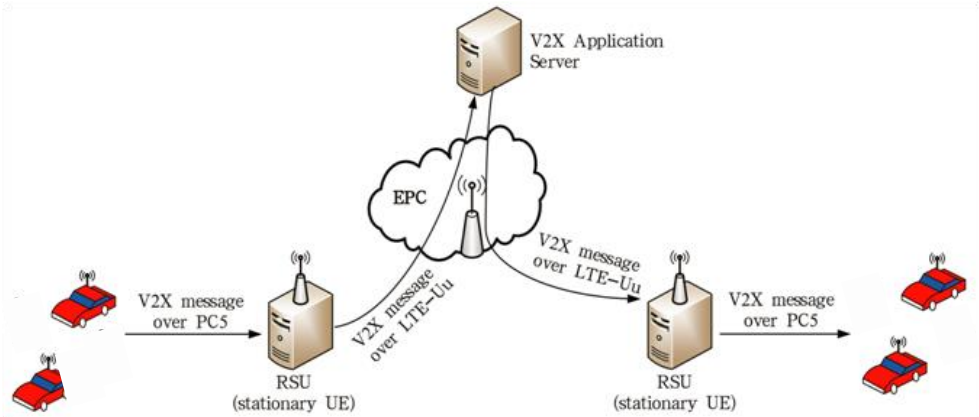


Figure 8. PC5 and LTE-Uu-based mixed V2X communication scenario (3GPP, “Initial Cellular V2X standard completed”; September 2016.)

C-V2X based communication system consists of roadside system, which is used to detect the common parking space information and integrate the parking space information;

5G communication module, which is used to receive and send the car location information sent by roadside system; and the vehicle subsystem, which is set on the vehicle to receive the common parking space information transmitted by the 5G communication module, and the parking space information is processed, analyzed, and converted into singles that can be understood by drivers such as sound and light. The system can connect the parking space information with the vehicle, and transmit road information to the drivers, thereby ensuring the driver to understand the parking space information of the nearby areas, and increase the convenience and safety of the parking.

### 3.2.2 Dynamic V2X communication system model

To achieve the initial vehicle to everything coordination and solve realistic parking issues, besides the system framework and basic infrastructure, moreover, a dynamic communication system modeling the figure 9 is needed.

This multi-tasking model can be used to illustrate the realization of reasonable sharing of parking in the parking area, or the dynamic scheduling of parking spaces and the reliable information exchanging with the parking space demanders.

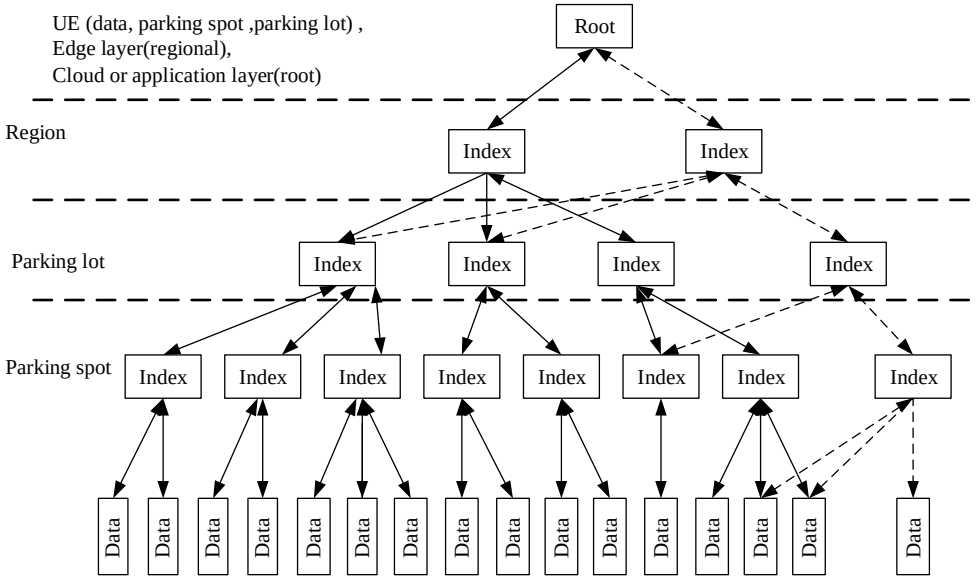


Figure 9. Communication system model.

Index: Standing for essential, but various forms of transmission nodes or gateways in 5G network architecture, such as handsets, moving vehicles, servers, third-party applications. Through the communication protocols and this algorithm model, session coordination in between, data collecting in physical layer or even computing in upper edge layer work could be applied in the delivery transmission and backhaul in 5G V2X network.

Data: the anchor in model contains the features of the sharing parking space and vehicle information etc.

Application : In the highest communication layer, standing for concept or nodes, system in network model, for example, regional server, 5G core network etc.

The conditions for matching request in the dynamic scheduling queue processing model of this paper include the following eight aspects:

- Neighboring parking relocation information
- Estimated time to reach the target location
- Charging categories
- Parking and service capacity
- Parking time shift
- Distance between parking space and vehicle;
- Location of targeted parking space and vehicle;
- Parking record database

One of the V2X advantages is the consolidation of information and services provided by various third-party applications and operators, from which the real-time information exchange and seamless V2X connection could be achieved.

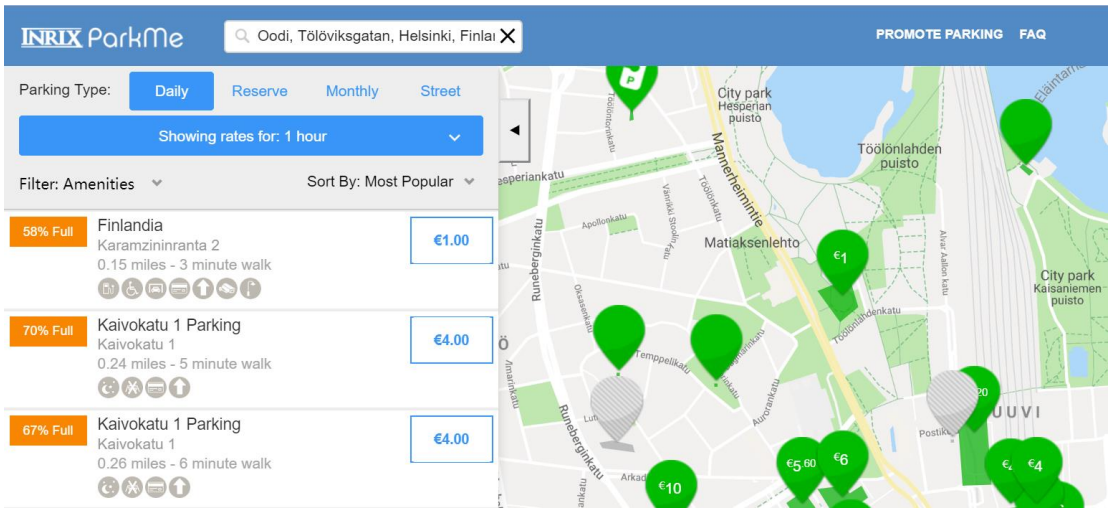


Figure 10. Oodi parking info(Park Me webpage, 2019)

V2X servers will synchronize the parking info to the UE or On-board-unit (OBU) installed in vehicles. For example, the info shown in Figure 10, the Park me website page, commuter can find the available parking area around Oodi library, the parking capacity and road mapping etc.

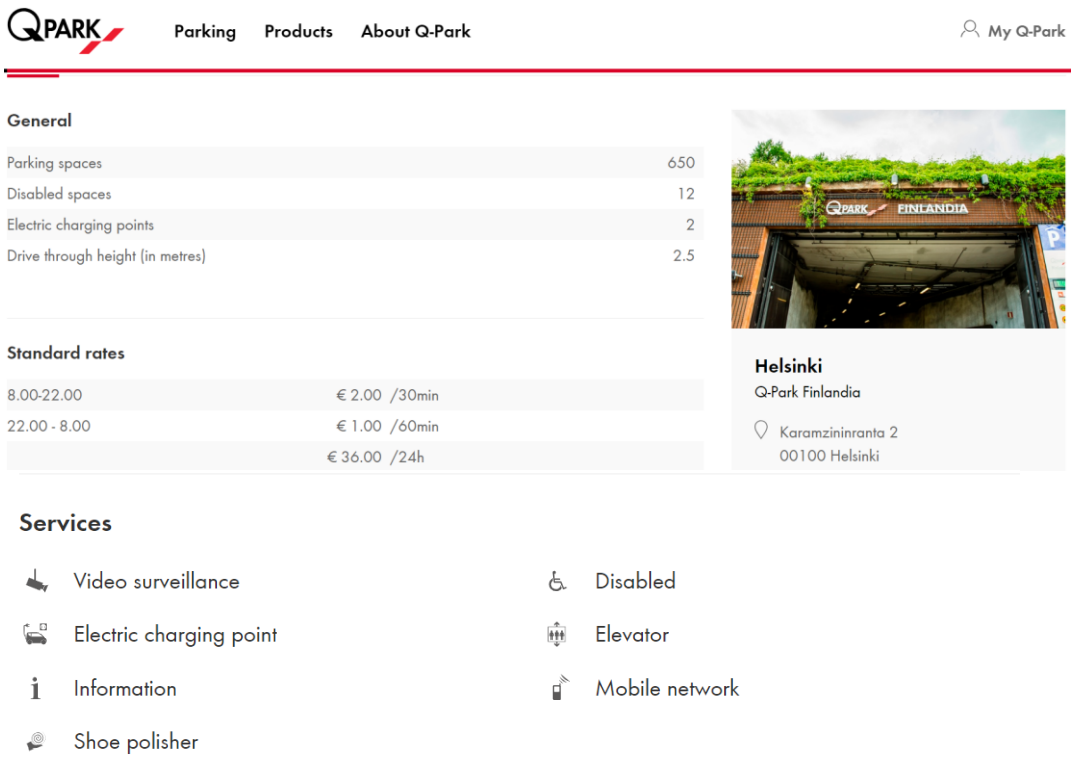


Figure 11. Finlandia parking lot (Q-park webpage,2019)

Car parks operator in Finland like Q-park, presents the general layout of parking area, address, spot count and charging rate by different time shifts, and service categories for the entered customers.

The user mobility data which contains 8 criteria above will be collected and transferred to the index or root in upper layer for further analyzing or computing etc., Real time parking coordination will be triggered within the parking space information sharing system.

Through V2X communication link in 5G RAN, IaaS capture and track real-time vehicle/user mobility and neighboring conditions, V2X communication will be hosted among vehicle, shared-parking area and parking service platform with the 5G SBA and Mobility Edge Computing (MEC) technology showing in Figure 12.

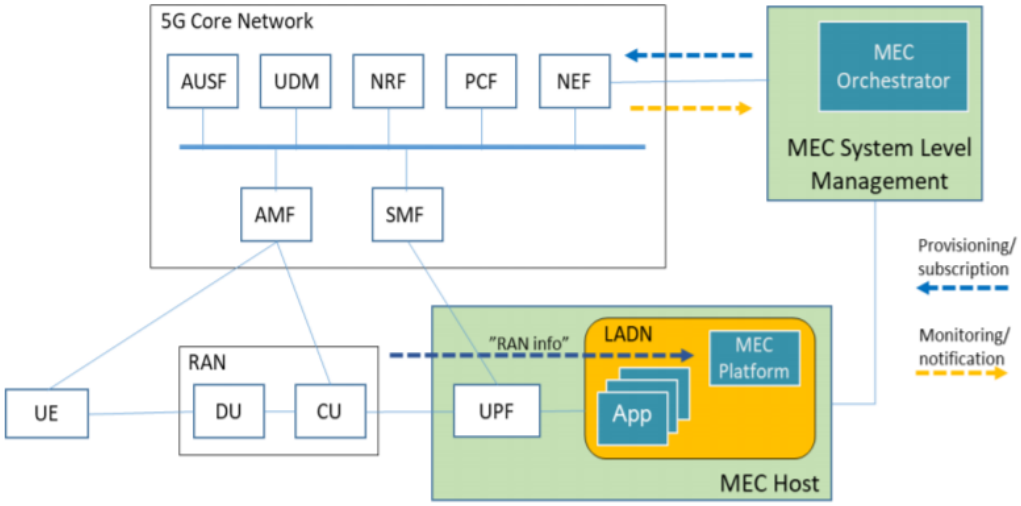


Figure 12. Capabilities exposure deployed with Local DN (MEC white paper,2018)

MEC system can access user plane and control plane in 5G using various APIs, the network functions, such as NEF-network exposure function connect MEC system directly with core to leverage the integration work of SBA and MEC system. MEC system is applied the edge of FaaS, sessions are able to be proceeded and synchronized to achieve V2X applications, such as dispatching parking spots to an individual application user or directly a vehicle fleet for parking traffic steering.(Sami et al.,2018)

# 4 Conclusion

According to Helsinki parking brochure, government will develop sustainable parking solution which adapt to currently limited road resources case. This plan is designed to be supportive for residents' quality of life and competitiveness of business sector for at least ten years. This proposal naturally relate to the advantages of the value-added service above the PSTN, especially that control plane separation from user plane in 5G core and the communication path from landline to the wireless. Utilizing 5G V2X technologies, little attention is needed on parking lot reconstruction or long-run vehicle evolution, because 5G provide possibility of internet of things, and stage of future parking policy development.

Based on the situations of parking sharing in Finland, this work briefly introduces the emerging 5G communication technology andV2X technology. A parking space-information sharing system is then introduced consisted of parking space searchers, shared-parking space, and parking service platform. Furthermore, a dynamic dispatching model is developed containing eight optimization discriminating indicators in the parking dynamic dispatch queue processing model. Combined with the parking space information sharing system, the broadcast of the parking spaces that meet the above eight conditions can be realized, as well as the parking space information sharing for those who meet the parking space requirements.

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