# Cellular-V2X and VANET(DSRC) Based End-to-End Guidance for Smart Parking

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**Abstract.** Nowadays, Vehicle-to-everything (V2X) is one of the main emerging technologies attracting significant interest of researchers and industries who aim to improve traffic efficiency. C-V2X which stands for Cellular Vehicle-to-everything is a technology that enables communication between vehicles (V2V), vehicles and infrastructure (V2I), vehicles and pedestrians (V2P), and vehicles and other devices (V2D) using cellular networks (LTE or 5G). DSRC which stands for Dedicated Short-Range Communication Standard, specifically IEEE 802.11p, is a communication standard enabling vehicles to exchange real-time information with each other and roadside infrastructure within short distances. VANET DSRC's main purpose is to enhance road safety and improve traffic efficiency. Another essential system which in turn contributes to improved traffic efficiency and reduced congestion in urban areas is the Smart Parking System (SPS). SPS is a technology-driven approach to managing parking spaces more efficiently. In This paper, integration of a Smart Parking System with C-V2X and VANET(DSRC) is proposed, we suggest a new C-V2X and VANET (DSRC) based End-to-End guidance scheme for smart parking. The C-V2X network provides external guidance in this system, while the VANET (DSRC) infrastructure handles internal guidance. By integrating both external and internal guidance, we offer parking users a comprehensive End-to-End guidance experience. This paper introduces the fundamental aspects of the proposal, which will be further developed and validated through simulation in our future works.

**Keywords:** Smart Parking · Parking Guidance · VANET · DSRC · Cellular-V2X · Internal Guidance · External Guidance

## 1 Introduction

VANET and C-V2X are two related but distinct technologies for enabling communication between vehicles and between vehicles and their surrounding environment such as network, infrastructure, and pedestrians. VANET [1] is an emerging technology, the term Vehicular Ad Hoc Network associated is developed and standardized under the umbrella work of intelligent transport systems (ITS) [2]. VANETs are a subset of Mobile Ad Hoc Networks (MANETs), which


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are known for their dynamic topology, self-organization, and absence of a fixed infrastructure, it allows different deployment architectures in highways, urban and rural environments. VANET uses vehicles as nodes equipped with Onboard Unit (OBU) creating a wireless network for communication and information sharing among vehicles and with roadside infrastructure (RSU). Communication in VANET is enabled through the use of IEEE 802.11p recognized as "Wireless Access in Vehicular Environments" (WAVE), developed specifically for VANET communications and it allows different deployment architectures in highways, urban and rural environments (Fig. 1). The main motivations behind VANETs include enhancing road safety and optimizing traffic efficiency [1].

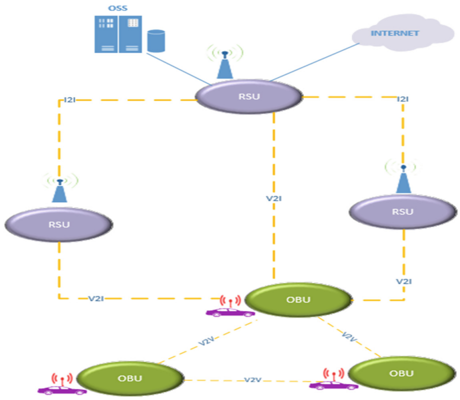


**Fig. 1.** VANET DSRC/WAVE architecture.

C-V2X (Fig. 2) is the technology developed within the 3 Generation Partnership Project (3GPP) and designed to provide wider coverage and higher data rates compared to VANETs. It encompasses both direct vehicle-to-vehicle (V2V) and vehicle-to-everything (V2X) communications [3]. C-V2X stands for cellular Vehicle-to-Everything operates in tow modes, direct mode (PC5) and network mode (Uu interface) [4]. In direct mode, often referred to as PC5, communication takes place directly between vehicles and infrastructure without relying on a cellular network. Network mode, also known as Uu, involves communication between vehicles and infrastructure using the cellular network infrastructure.

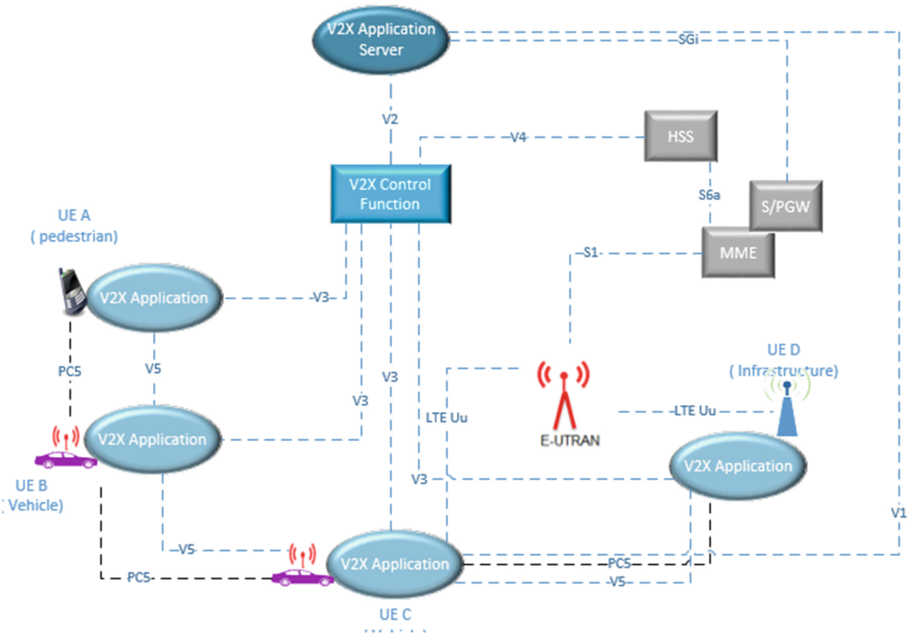


**Fig. 2.** 3GPP LTE C-V2X architecture.

*Network Communication V2N (Uu Mode):* C-V2X can connect vehicles to cellular networks, enabling them to access cloud-based services, traffic updates, and other relevant information.

*Direct Communication V2V and V2I (PC5 mode):* The direct mode, referred to as the PC5 interface, enables vehicles to communicate directly with each other (V2V) and with roadside units (V2I) without the need for cellular networks.

The 3GPP LTE standard's Release 14 introduced several new network architecture entities to fulfill the requirements for supporting V2X communications.

These entities include:

- V2X Control Function: Supplies configuration parameters for the vehicular UEs(cars) for both in-coverage and out-of-coverage UEs.
- V2X Application Server: Handles a majority of the network functions associated with V2X. This encompasses receiving uplink V2N messages, disseminating unicast or multicast data to vehicular User Equipments (UEs)...
- V2X Application located on board of each vehicular UE or RSU that communicates with the V2X Application Server.

have the common goal of enhancing road safety, optimizing traffic efficiency, and delivering infotainment services. From the performance perspective, C-V2X was explored as an alternative or complementary technology due to the limitations of VANET (DSRC) and was expected to improve performance of vehicular communications (V2X) [5]. IEEE 802.11bd and 5G-NR are the next generations for respectively VANET-DSRC (IEEE 802.11p) and LTE Cellular-V2X [6] (see Fig. 3).

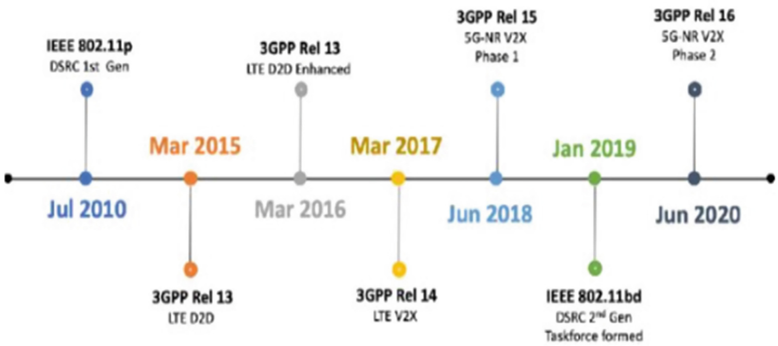


**Fig. 3.** C-V2X and VANET DSRC standardization.

Beside C-V2X and VANET (DSRC), Smart Parking System (SPS) is also a key element in smart city context. Smart parking system is an essential component witch is expected to play a considerable role in traffic efficiency especially in urban area. The smart parking concept combines traditional parking methods with recent technologies, including the Internet of Things (IoT), Radio Frequency Identification (RFID), Wireless Sensor Networks (WSN), Ultra-WideBand (UWB), Artificial Intelligence (AI), Cloud Computing (CC), and others. Smart parking strategies encompass various technologies and approaches designed to optimize parking management and improve parking experience [7].

Guidance plays a crucial role in smart parking system by enabling drivers to easily locate parking spaces. There are two distinct methods, outdoor and indoor guidance, employed to assist individuals in reaching their destinations [8]. In the realm of smart parking, external guidance systems are created to aid navigation through outdoor spaces like city streets, parks, or campuses. Meanwhile, indoor guidance systems are specifically designed to assist people in navigating through enclosed spaces such as airports, hospitals or shopping malls. For external localization in open spaces Global Navigation Satellite Systems (GNSS) such as Global Positioning System (GPS), GLObalnaya NAvigatsionnaya Sputnikovaya Sistema (GLONASS) as well as GALILEO have demonstrated high efficiency. Indoor systems typically utilize technologies such as Bluetooth beacons, Bluetooth Low Energy (BLE), WiFi, Zigbee, UWB, RFID tags to provide location information. Additionally, visual cues such as signs or arrows, maps can be utilized to provide directions and facilitate individuals in finding the route to the parking spot.

The remainder of the article is structured as outlined below: Section 2 delves into discussions on guidance within the context of smart parking. In Section 3, an analysis and critique are presented concerning existing works that address guidance in smart parking. Section 4 introduces our proposed End-to-End parking guidance scheme. Finally, Sect. 5 is dedicated to concluding remarks and considerations for future work.

## 2 Related Works

One widely adopted application in smart cities involves the deployment of intelligent parking solutions. These solutions enable individuals to optimize their time, decrease fuel consumption, and reduce carbon dioxide emissions, ultimately contributing to the enhancement of traffic efficiency within the smart city. Guidance for drivers in parking is a pivotal component of smart parking systems. It employs computer technology, communication mechanics, control techniques, and more to offer driving route suggestions, berth order, traffic state forecasts, and additional services based on a traveler's driving destination and current traffic conditions. The primary objective is to guide drivers in anticipating available parking spaces.

The state of the art define two parking guidance solutions, outdoor parking guidance and indoor parking guidance [9]. For the parking external guidance, the widely used technology is Global Positioning System (GPS), GPS give real time location and guidance toward outdoor destination. GPS signals experience signal weakening and exhibit restricted penetration capability when used indoors. In indoor areas such as shopping malls, airports, etc., rather than the classical methods used for guiding drivers inside, which are based generally on panels, screens and directions, different technologies could be used to provide positioning and route drivers to the free parking slot.

WIFI, Bluetooth Low Energy, Zigbee, RFID and UWB are the technologies widely used in indoor positioning solutions [8,9]. A WiFi-based positioning parking guidance system is proposed in this work [10], a system framework composed of ultrasonic, databases, location server, web server, and mobile app is developed, with the use of fingerprint technique for positioning.

In [11], a straightforward parking system utilizing Bluetooth Low Energy (BLE) is created and implemented. The system assigns a unique BLE beacon to each parking spot, offering users guidance to available parking spaces and incorporating a secure, automated payment system based on real-time usage.

In this study [12], a parking management system is designed using RFID technology along with wireless RF ZigBee to control and manage parking spaces. An Indoor Parking Guidance System has been successfully developed and designed accordingly.

In [13] an indoor parking guidance system for multi-level building based on wireless networks sensors and ultrasonic sensors prototype is developed and tested for only one floor. The solution can be extended to a building with multi floors.

In [14], authors explore an intelligent parking guidance system utilizing computer vision. The study delves into the essential technologies of a real-time parking recognition system founded on image recognition. Additionally, the paper discusses a vehicle guidance system based on the Dijkstra algorithm.

In [15], a novel smart parking system (SPS) scheme known as SPARK is presented, leveraging Vehicle Ad Hoc Networks (VANETs). SPARK introduces three crucial use cases, including real-time navigation for users. The system involves Roadside Units (RSUs) actively monitoring parking areas to ensure users receive current information on available parking spaces, facilitating efficient navigation to the nearest open spots. A comprehensive review of VANET localization techniques is conducted in [16].

In [17], R. Raghu et al. introduce an Effective Dead Reckoning Approach for forecasting a vehicle's future position. The algorithm uses the current position of the vehicle to anticipate its future location. This is accomplished by taking into account a forthcoming time-space window, allowing for a precise estimation of the vehicle's future position.

## 3 Analysis and Critical

Indeed, Global Navigation Satellite Systems (GNSS) demonstrate exceptional efficiency in external localization within open areas. Nevertheless, their effectiveness diminishes in indoor environments such as malls, tunnels, and enclosed spaces. In such situations, GNSS signals may encounter obstruction or weakening, leading to decreased accuracy or even signal loss. In a smart parking system, GNSS is employed to offer external guidance, assisting drivers in reaching their intended destinations.

The predominant strategies for smart parking systems primarily emphasize external guidance, typically relying on GPS and maps to provide drivers with instructions on reaching the parking facility. There are only a limited number of studies that delve into providing guidance specifically for parking inside smart parking environments. Moreover, with respect to the literature, the concept of End-to-End guidance in smart parking has not been previously addressed. The End-to-End guidance system is a navigation system, combination of external guidance and internal guidance, which provide route and instructions for drivers to reach directly their booked parking free slot inside parking facility.

Each of the previously mentioned technologies has the capability to offer either outdoor localization only or indoor localization only or a combination of both [Table 1].

**Table 1.** Positioning technologies

| Technology | Positioning Type | |
|---|---|---|
| | Outdoor | Indoor |
| GNSS | * | |
| WIFI | | * |
| Bluetooth | | * |
| BLE | | * |
| RFID | | * |
| UWB | | * |
| Zigbee | | * |
| Hybrid (VANET + C-V2X) | * | * |

## 4 Proposal

To the best of our knowledge, this work is the initial endeavor to introduce smart parking services into the domain of cellular vehicular networks (see Fig. 4). C-V2X and VANET (DSRC) technologies exhibit a key advantage by providing both external and internal guidance in smart parking, enabling an End-to-End (E2E) parking guidance experience.

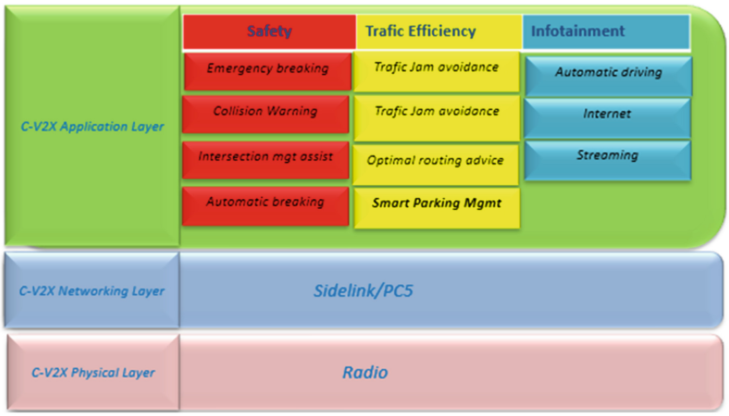


**Fig. 4.** C-V2X: Smart parking use case.

We leverage these two emergent and extensible technologies, C-V2X and VANET (DSRC), to propose an End-to-End parking guidance scheme (see Fig. 5).

Our smart parking management approach is based on C-V2X and VANET dual mode RSUs (C-V2X mode and DSRC mode support). the C-V2X provides

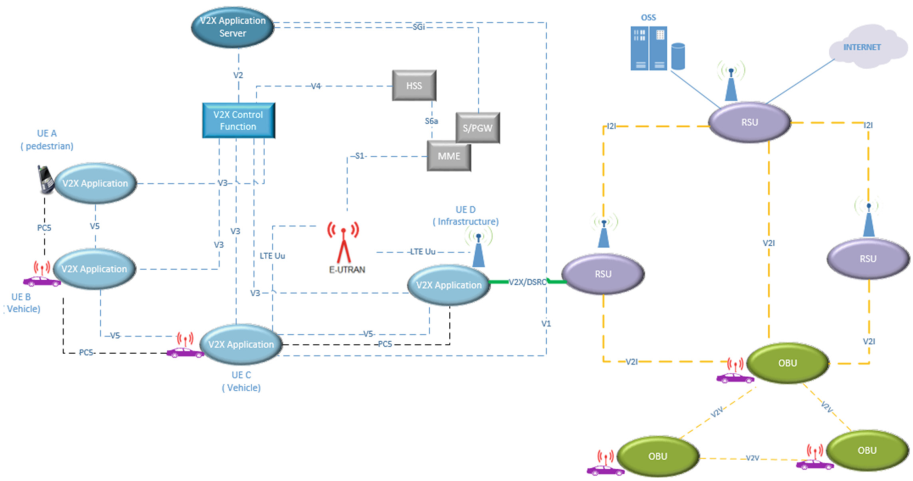


**Fig. 5.** C-V2X and VANET (DSRC) interoperability architecture for smart parking use case.

online reservation, payment, parking location and route to reach the parking. While the parking status (free/busy spot), entrance, exit is controlled by the RSUs installed in the parkin space. A smart parking application server is used to host all the parking related information.

*External Guidance:* The network communication (V2N) provides internet access and optimised route to reach a parking destination. In C-V2X context, devices have access to the internet as well as to cloud based services and applications servers through Uu interface. Therefore, in our proposed scenario, the smart parking information such as availability lots, payment, and optimal route is hosted by the V2X application server. These information is retrieved through V2N communication (vehicle communication with application server) and displayed on the vehicle screen.

*Internal Guidance:* Once the driver arrives to the entry of the parking, the direct communication V2I provides instructions and optimised routes to vehicle's driver in order to reach the free spot inside the parking. A large parking could be an airport, mall, hospital or university, etc. The navigation through these kind of building is not possible through GPS. A set of Road-side-unit (RSU) are installed around the parking space. The vehicle and RSU specifications are as follow:

- V2I communication at the entrance, inside and exit of the parking.
- The parking space spot status (free/busy) is recorded in The RSUs database. Updates are regularly sent to the smart parking application server.
- Dual mode RSU: The RSUs are equipped with two different modes of communication: DSRC for Vehicle-to-Infrastructure (V2I) communication and Cellular-V2X mode for Infrastructure-to-Network (I2N) communication (to share parking status with smart parking application server).

- The RSU hosts the online map: the online map is used for indoor navigation, typically designed to help drivers navigate and locate specific spot within the parking.
- The vehicle is equipped with an dual mode OnBoard Unit (OBU) for V2V, V2I and V2N communication.

At the entrance of the parking, the vehicle and RSU initiate V2I communication. This exchange between the RSU and the vehicle aims to authenticate, authorize and then guide the vehicle to its reserved parking spot:

- Authentication phase: RSU triggers the authentication phase by challenging the vehicle to authenticate itself. Various authentication criteria could be used during this phase (keys, plat number, RFID tags...).
- Authorization phase: The RSU determines whether the vehicle is granted access to the parking facility or not. Typically, this decision relies on the payment status, indicating whether the driver has paid for parking or not.
- Positioning technique: fingerprinting, Trilateration or Multilateration are the widely used techniques in the field of wireless positioning and location-based services. While fingerprinting involves creating a database of signal strength patterns (fingerprints) at various locations within a given area, and then when a device wants to determine its location, it measures the signal strengths of nearby Wi-Fi access points, Bluetooth beacons, or other wireless signals and compares these measurements to the stored fingerprints in the database. The technique relies on signal strength data, called RSS (Received Signal Strength), which represents the distance of each beacon or sensor from a user's device. Trilateration/Multilateration is used to determine the position of a device based on its distance measurements from at least three reference points with known coordinates. Vehicle localization is achieved using V2I communication, in which the RSUs installed in the parking facility calculate the vehicle position using the positioning technique.
- Guidance phase: Subsequently, based on the previous phase result, the route towards the free spot is displayed on the vehicle screen or driver's phone.

*End-to-End Guidance:* End-to-end guidance is the combination of external guidance and internal guidance. The external guidance provides assistance to vehicles and individuals by giving them precise location information and directions. The parking location stored in the smart parking application server database is requested by the driver through V2N communication, and subsequently, the GPS is involved in route calculation.

On the other hand, the internal guidance assists the driver in the process of parking their vehicle. Once the driver arrives at the parking entrance, and after successful authentication and authorization procedures, the drivers use the online map downloaded by RSU on the vehicle OBU and displayed on the screen, or alternatively, the driver may have previously downloaded this map onto their vehicle or smartphone. Subsequently, after entering the parking zone, the wireless communication (V2I) between the vehicle and the RSUs in place started in order to calculate the vehicle localization utilizing fingerprinting approaches as it can provide high accuracy in indoor environments. then the driver follows the route displayed on the online map to the free spot.

## 5 Conclusion

This paper presents a novel smart parking guidance system that utilizes the promising capabilities of Cellular-V2X (C-V2X) and VANET (DSRC), an evolving and adaptable technologies. The objective of this scheme is to enhance the management of parking lots and offer a comprehensive End-to-End guidance service for vehicles, covering both external and internal aspects. Our subsequent efforts will delve deeper into the architecture and procedures of the proposed scheme. Moreover, we aim to develop a model for our solution and then perform a simulation to validate its functioning. The modeling step consists of developing a model where we define the components and the data flow of the system; the system involves "parking facility position" and "parking spot ID " as inputs, and provides "external guidance" and "internal guidance" as results. To validate our model, we will choose the most appropriate simulation tools namely traffic and network simulators. By performing these simulations, we will be able to extensively evaluate and validate the effectiveness and performance of the proposed scheme.

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