An InfoStation-Based Context-Aware On-Street Parking System

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***Abstract*—This paper presents a novel vehicle ad hoc network (VANET) based on an on-street parking system that exploits the concept of InfoStations (ISs) and context-aware systems to locate and reserve a parking space. All parking zones have an assigned IS that provides wireless coverage to that parking zone. Thus, the parking details are available over dedicated short-range communication (DSRC) via the IS. Vehicles can request and reserve a preferred parking space using wireless capabilities while still moving. Because parking zones are generally distributed according to street (area) names, the architecture in this paper recommends centralised IS, which monitors and controls the geographically intermittent area-wise parking zones.**

Keywords—VANET; Context-aware; InfoStation; On-street parking.

I. Introduction

With the recent developments in context-aware systems and IS (InfoStation)-based VANET (vehicle ad hoc network), research in the field of intelligent discovery and reservation of on-street parking spaces has gained considerable momentum. The most important goal of these activities is to find ways to make parking space discovery and reservation more comfortable and efficient to prevent unnecessary and time-consuming delays, wasting of fuel and environmental pollution and to reduce driver frustration.

VANET, a specific application of mobile ad hoc networks (MANET), makes possible the DSRC (dedicated short-range communication)-based communication between moving vehicles, popularly known as vehicle-to-vehicle (V2V) communication. With the emergence of IS, DSRC has found applicability as a communication medium between the vehicle and the infrastructure, known as V2I communication [4] [10].

To meet the demand of drivers for a more flexible and comfortable parking spot location and reservation system, we propose an architecture in which the driver can request parking from the vehicle's on-board unit (OBU). The IS processes the request and stores the parking policies, i.e., whether the parking is suitable for small or heavy vehicles, whether it is open for all drivers or reserved for disabled drivers. The driver transmits his or her desired parking preferences, a few details of the vehicle and his or her drivers' license details. The IS compares these details with the parking policies and replies suitably to the vehicle, as mentioned later in the following sections.

The novel approach presented in this paper makes use of basic and easily available information to locate and reserve a parking space. This information is comprised of the vehicle profile, i.e., the size and type of the vehicle, and the driver profile, i.e., the driver's name, license number and medical conditions. This information also includes knowledge of the exact location of the vehicle obtained through the location sensor and that of the parking environment obtained through the vehicle surround sensors, which work based on ultrasonic wave emission technology. Figure 1 shows a basic on-street parking system scenario with all of the involved components, i.e., the GPS satellite, the ISC, a number of ISs, vehicles, on-street parking zones, parking prices charged by an IS and the communication between various components.

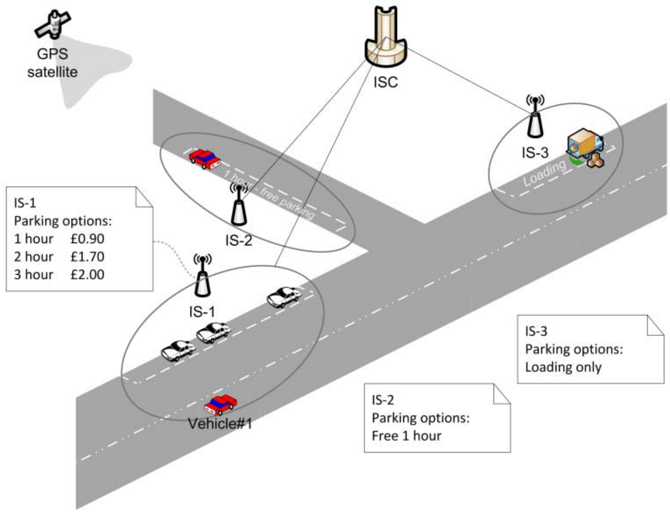

Figure 1. On-street parking system scenario

The IS-based context-aware on-street parking system offers numerous improvements and significant advantages over existing parking reservation systems, as follows:

- According to prior research, systems exist that use an SMS cellular service to locate and reserve a parking space. In the IS-based system, low-cost DSRC wireless communication networks are utilised, thus reducing the cost incurred by expensive cellular networks.

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- Payment for a parking space is done wirelessly using the OBU, an IS and the InfoStation Centre (ISC), which eliminates the need for individual payment machines for each parking zone and coin-based payment systems.
- Our approach is low in cost because it uses inexpensive sensors that are already mounted on the vehicle's bumpers. This implementation eliminates the need for costly sensors to be mounted in parking zones.
- Our system does not require setting up more parking spaces but assists in managing the already available parking space.
- Drivers can search for a parking space while still on their way to their destination, which saves time and prevents wasting considerably scarce fossil fuels when unnecessarily searching for parking.

The entire VANET architecture of the paper revolves around the concept of IS and context awareness. The organisation of the rest of the paper is as follows. Section II describes the architecture of our proposed context-aware on-street parking system. It shows three-tier-based network deployment and explains the architectural components in detail. Section III presents our proposed method for the reservation and payment of parking through the IS with the assistance of an activity diagram that shows the step-by-step process of reserving a parking space. Section IV describes a detailed activity diagram that defines the steps followed to locate the vacant parking space in the on-street parking zone. Section V provides details of the related work that has been carried out and to which our work extends. Section VI concludes the paper with the findings of the work and draws attention to the scope of future work.

II. System Architecture

The architecture of the locating and reserving on-street parking system is based on the interaction of the IS and context-aware systems. Figure 2 illustrates the three-tier network deployment, which is the foundation of the entire architecture, including the context-aware features. The nodes are organised in a manner such that each tier performs a dedicated function.

The first tier shows the vehicles, each with its own OBU. The OBU utilises DSRC for communication with the neighbouring vehicles and with the IS. DSRC-based communication allows vehicles to exchange data with the IS only when a vehicle falls within its coverage area. Vehicles might fall inside the range of an IS (V2I) or might fall outside the range of an IS (V2V). When a parking space is needed, the OBU sends the request message to the IS [11].

The second tier is the IS, which stores information on the parking policy and compares the request message contents with the parking policies. The IS offers on-road wireless coverage at high speed and acts as the medium to provide an extension of the DSRC to vehicular networks. ISs are proposed in the context-aware on-street parking reservation system to make the best use of channel efficiency and to simultaneously replace conventional hardware, such as parking access barriers, payment machines, paper-based parking slips and parking attendants [5] [11]. A few characteristics of IS are outlined below:

- IS enables wireless communication in vehicular environments at a high data rate over discontinuously spread parking zones [11].
- Each IS is usually deployed for a small coverage area, and the vehicle is expected to stay in a coverage area during the time of communication. If a vehicle finds itself out of the coverage area, V2V communication is available [11].
- IS may be used to provide other services, such as Internet, weather conditions, traffic status, etc.

The third tier is the ISC, the local traffic authority that acts as a controller of the ISs and maintains a few ISs covering a particular geographical area. Basically, ISC performs the following functions:

- ISC assists the IS in finding alternative parking for a vehicle when a mismatch is detected. A mismatch indicates a difference between the vehicle profile, the driver profile, drivers' parking preferences and the desire parking policies. Examples of such a mismatch is a cargo van that requests a loading parking space designated for private vehicles or a driver with no disabilities who requests a parking that is only for disabled drivers.
- Once a parking space has been booked, the ISC updates the IS and its own database, thus synchronising the parking reservation process.
- The ISC is the most secure point of communication; therefore, the payment transaction takes place here.
- Whenever the IS policies need to be updated, they can be done through the centralised ISC.

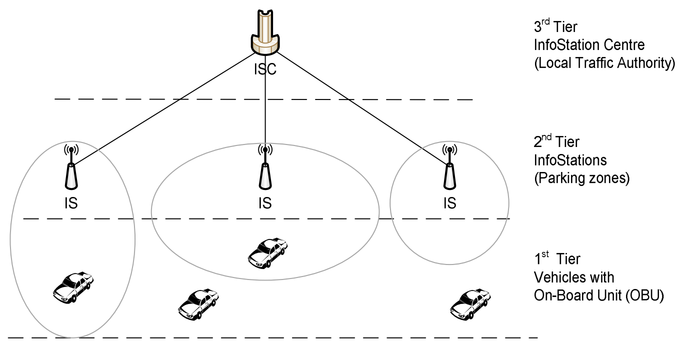

Figure 2. Three-Tier System Network Deployment

Next, we move to the detailed architecture, wherein we address the individual system components and explain the tasks carried out by the network deployment. Figure 3 shows the proposed on-street parking system architecture that consists of three separate nodes (blocks): a. the vehicle block, b. the IS block and c. the ISC block, described as follows:

A. The vehicle block

In Figure 3, the vehicle block contains surround sensors and location sensors. The surround sensors sense the information about the objects and obstacles in the vehicles' vicinity and help locate a vacant space in the parking zone. The global positioning system (GPS) sensors capture the vehicle's current location and assist the preloaded digital map to find a parking space near the vehicle's stated destination.

The OBU employs a set of UIs to interact with the vehicle drivers in different ways. It may provide visual displays, buzzer alerts, speech enunciators and keypad interfaces to reflect application actions [14]. The data repository unit on the OBU also holds information on the vehicle and driver profiles. The OBU also relies on the preloaded digital map, which provides the navigation system with necessary information such as parking services. The processing (reasoning) unit is the core of the OBU and is responsible for controlling and coordinating the operation of other OBU components. The processing unit also obtains meaningful information from the contextual knowledge acquired by the sensors and is responsible for implementing the parking request services.

The processing unit is connected to the communication unit of the vehicle that has a DSRC control unit coupled to the transmitter and the receiver interface. This interface allows the communication unit to exchange messages with the OBU of other vehicles (V2V) and with the communication unit of the IS (V2I) [15].

A brief account of the contents of the request message is given as follows:

- *Vehicle profile*: The vehicle profile consists of the vehicle registration number, vehicle type and vehicle size.
- *Driver profile*: The driver profile consists of information on the driver's license number, name and medical conditions and whether he or she holds any parking permits.
- *Parking preferences*: The parking preferences specify the type of parking space the driver wants, such as a parking space offered free of cost or near the destination.
- *Parking destination*: Specifies the waypoint from which the driver wants to book the parking space.
- *Parking duration*: Specifies the time the driver wants the parking space.

B. The IS block

In Figure 3, the IS block contains the information on the up-to-date parking zone policies and the available parking space stored in the data repository unit.

The availability counter unit monitors the parking zone to determine the free spaces based on the sensor information. The prime objective of this unit is to provide the parking system with information on available parking spaces and lot size. If the availability counter shows a parking space as available, then the policy interpreter compares the contents of the request message (i.e., vehicle profile, driver profile, parking preferences, parking destination and parking duration) with the parking policies of the IS. For example, a driver without a disability may request a parking spot reserved for a disabled driver. The policy matching needs to rectify this discrepancy by unit based on parking zone policies.

Lastly, the process unit represents the IS processor and coordinates and synchronises the activities between the units inside the IS. The process unit makes a conclusion about the match or mismatch previously mentioned and takes suitable action. If there is a match, then the IS replies to the OBU through the wireless DSRC, stating the availability and the various payment options. In case of a mismatch, the request is forwarded to the ISC through either a wireless or a wired communication medium.

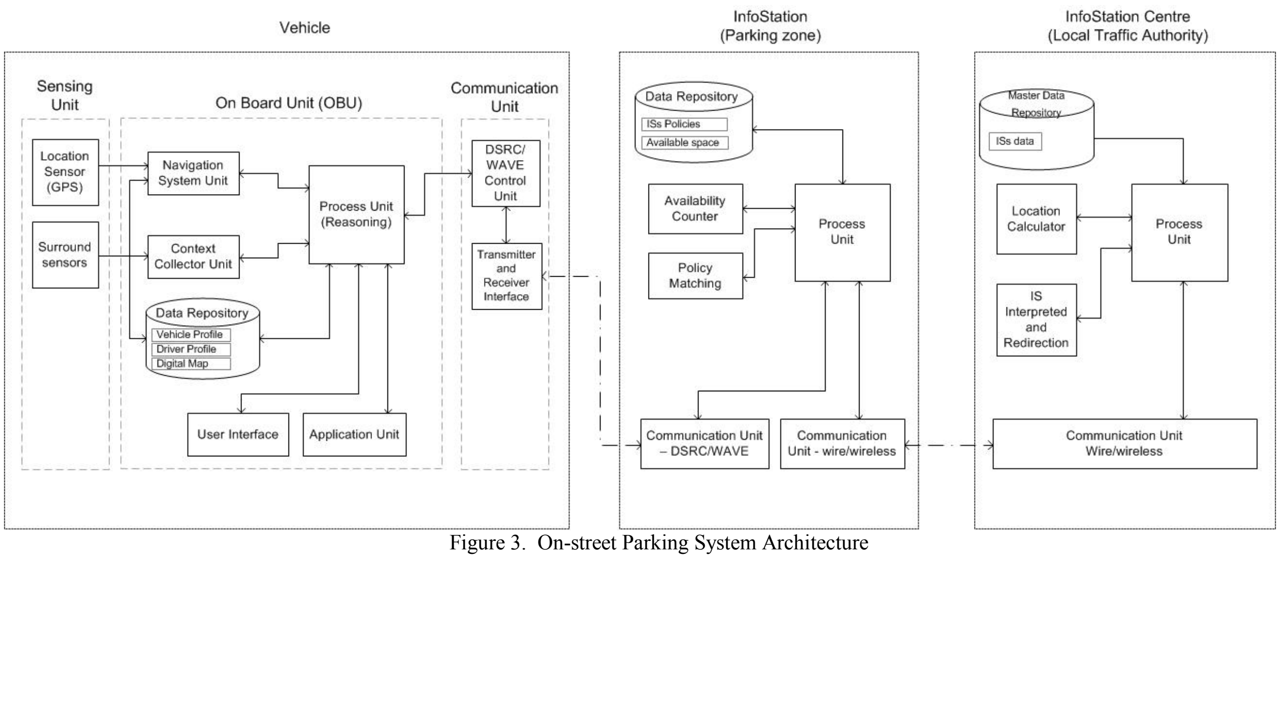

Figure 3. On-street Parking System Architecture

C. The ISC block

In Figure 3, the ISC block monitors and controls all ISs across the system and represents the core of the IS concept. The main function of the ISC is to update and synchronise the parking service information to keep all ISs updated.

The master data repository unit contains updated information (i.e., serial number, location, policies and available parking lot size) on all ISs under the particular region's ISC.

When an IS forwards a request to the ISC using the IS 'interpretation and redirection block', the location calculator unit first locates the nearest alternative parking zones based on the driver's desired destination. Once a few alternative parking spots are located, then the interpretation and redirection unit matches the request message contents with the parking policies and suitably responds to the OBU. The OBU is asked to choose from the available parking spots and to make the payment to reserve the parking. When a vehicle decides to make payments, the ISC again verifies the account details to make the appropriate debit. Once the account is debited and the parking is booked, the ISC then updates its database to synchronise the process.

The next section presents two separate activity diagrams, one for 'reserving the parking space' and the other for 'locating the vacant space'.

III. RESERVING A VACANT PARKING SPACE

Figure 4 represents the vacant parking space reservation process in the form of an activity diagram. The activity diagram divides the entire process into subparts shown by three swim lanes. The first swim lane represents the activities at the vehicle tier beginning with the vehicle's OBU sending a parking request message to the IS. The second swim lane represents the IS tier, which processes the received request from the vehicle and searches for an available parking space. The third swim lane represents the ISC tier, which controls the IS and administers the payment processes.

The parking reservation process begins with a vehicle searching for a parking space near a desired destination. The vehicle's driver enters the request from the OBU along with the vehicle profile, the driver profile and the preferences. The vehicle sends the request to the IS of the desired parking zone. The IS first checks the availability of the parking space:

a. *Available*: If at least one parking space is available for the required duration, then the IS checks the validity.
b. *Not-available*: If the desired parking zone has no available parking spaces, then the IS forwards the parking request to the ISC. The ISC scans the availability of all ISs and then redirects the parking request. Upon redirection, the ISC again scans for parking based on the usual contents of the request message and within the radius specified by the driver, for instance, 0.5 mile.

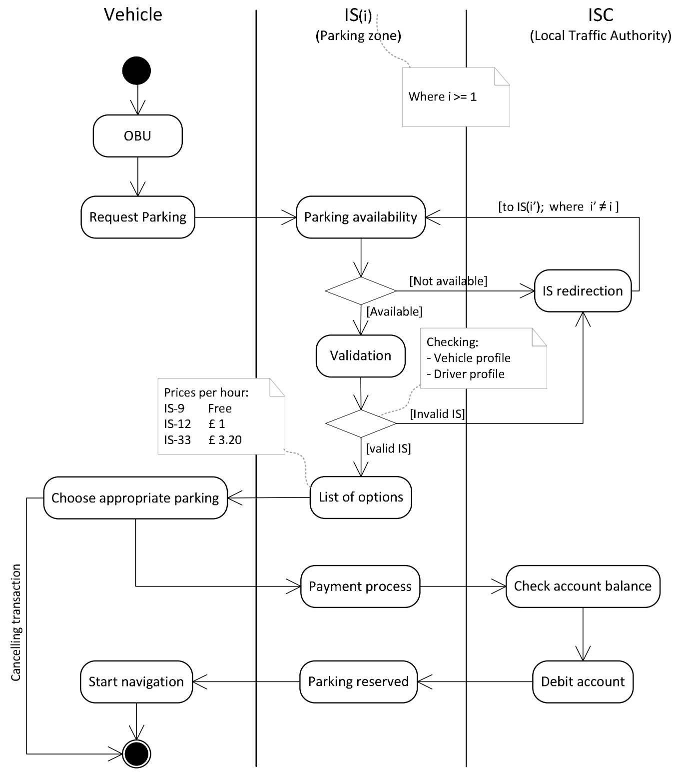

Figure 4. Reserving the Parking Space Activity Diagram

Once availability is determined, the IS validates the entire parking request. The IS breaks down the parking request to match the vehicle's profile, the driver's profile and the parking request with the IS policies:

a. *Valid*: means that the contents of the parking request match the IS parking policies;
b. *Invalid*: means that at least one aspect of the parking request fails to match this IS's parking policies; the request is then redirected to other ISs via the ISC.

Now, the vehicle driver receives a list of parking price options from different ISs (depending on parking duration). For example, the activity diagram shows three options being sent to the vehicle (the IS-9 is free parking, the IS-12 charges £1 per hour and the IS-33 charges £3.20 per hour). If the driver changes his destination choice and does not want to book a parking space from the current options, then the OBU presents an option to cancel the transaction. After cancelling the transaction, the driver can restart the navigation from the vehicle's OBU.

In contrast, if the driver wants to reserve a parking space, then he or she selects the appropriate space and replies back to the IS. The IS and the ISC process the reservation and the payment process. After the ISC successfully debits the parking payment, the IS sends the parking reservation acknowledgement to the vehicle driver. The driver now carries on with the journey to the selected parking zone and needs to arrive within the stipulated time (no later than 10 minutes from the scheduled time).

IV. LOCATING A VACANT PARKING SPACE

As previously noted, the main activity diagram in Figure 4 shows that the system checks the vacancy of the parking space in the parking zone regardless of its location and size. Therefore, the organising and calculating parking space activity diagram in Figure 5 was proposed to assist the IS in managing and utilising the parking zone's free spaces using the vehicle sensors. Importantly, note that the procedure to locate the vacant parking space runs in parallel with the procedure to reserve the parking space.

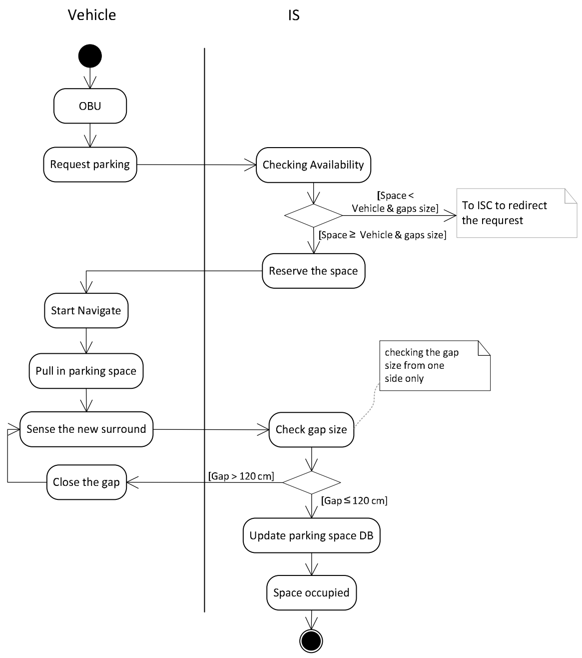

Figure 5. Locating the Vacant Parking Space Activity Diagram

In Figure 5, the IS side receives the parking request from the vehicle drivers. The task of the IS is to check the validity of the vacant parking space to suit the vehicle's size. Based on the vehicle information, the IS starts to match vehicle size with the vacant spaces list:

a. *Space ≥ vehicle and gap length:* The output of this transition means that the vacant space will be greater than or equal to the size of the vehicle, taking into account the gap between adjacent vehicles. In fact, the system should take into account free gaps between the vehicles to allow for pulling in and out. For instant, if the vehicle length is 300 cm, then 120 cm gaps need to be added at both the ends, or 300 +120 +120 = 540 cm.

b. *Space < vehicle and gap length:* A vacant space may exist in the parking zone that does not suit the vehicle and gap size. Therefore, the IS forwards this transition to the ISC to redirect the request to an alternative IS.

After reserving the appropriate parking space, the vehicle driver starts pulling in. The surround sensors check the new surroundings. The sensing data is sent to help the IS check the free gap between the adjacent vehicles:

a. *Gap > 120 cm*: When the gap size is larger than 120 cm on both sides of the vehicle, then the IS asks the vehicle driver to close the gap on any one side to eliminate the wasted free gap space between the vehicles.

b. *Gap ≤ 120 cm*: When the gap size is smaller than or equal to 120 cm on any one side, then the IS accepts the parked vehicle and updates the parking space database, marking the space as occupied.

When a vehicle enters the parking space after making the payment and exits when the parking duration is over, at both instances the ISC updates its database by decrementing or incrementing the number of available parking spaces and considers them for the next requests.

V. RELATED WORK

Recently, several previous studies related to parking discovery and reservation were presented in [5], [6] and [7].

In [6], Gongjun et al. proposed a wireless-based intelligent parking system especially applied to large parking lots. This parking system uses infrared sensors to sense vehicles and parking belts to control vehicle entry and exit. In our proposed architecture, the need for sensors on the parking spaces is eliminated. The parking system and the OBU use the surround sensors (already mounted on vehicle bumpers) to enhance the system's context-aware characteristic and then uses the collected information to calculate the size of the available space within the parking zone.

Verroios et al. [7] proposed a parking reservation system by deploying sensors on vehicles. Using VANET, the computational infrastructure informs the vehicle about available parking, but the vehicle has to determine the time needed to reach the parking space because that parking space may become occupied by another vehicle in the meantime and no provision exists to inform the first vehicle about the situation. We propose a payment-based architecture in which, once a vehicle books a parking space, other vehicles cannot use that parking space.

Panyappan [5] proposed a parking system that reduces the extensive and costly deployment infrastructure, and the available parking lots can still be located effectively. This proposal was restricted to parking lots. We extend this work by a further reduction in infrastructure and apply the architecture to on-street parking zones that demand a slightly more complex management structure compared with parking lots.

Kenny [10] emphasised various applications that widely use DSRC. These applications primarily consist of collision prevention and collision avoidance functionality. The architecture proposed by Kenny incudes OBU and IS. We extend the concept to ISC and utilise the high capacity DSRC channel for the comfort application of an on-street parking reservation.

Ghazy and Ozkul [12] integrated VANET with a roadside unit (RSU) to use DSRC to solve traffic congestion problems, and is both a safety and a comfort application. This application alleviates many unfavourable effects with respect to the health of the community, the economy and the environment during longer commutes. Our VANET-based architecture focused only on the parking spot location and reservation, whereas Ghazy and Ozkul took care of the traffic congestion issue.

Jie Sun et al. [13] proposed a sensor-based context-aware smart car that imparts a 'complex reasoning' faculty. The general architecture of these cars proposed wide use of various sensors on the sides of the car to sense data from the surroundings. We based our context-aware feature along the same lines by limiting the sensor to just two types: the surround sensor and the location sensor. In our architecture, the data collected by these sensors are sent to the IS, thus aiding the IS with better parking resource management.

VI. CONCLUSION AND PERSPECTIVE

This paper proposed a context-aware on-street parking system that combines the concept of context-awareness and an InfoStation (IS). We focused on designing a comprehensive three-tier parking system that utilises VANET and wireless DSRC to communicate between different nodes. The concept of context-aware OBU and the IS is the foundation of our architecture. Specifically, the information collected by the vehicle sensors assists the IS in locating, utilising and efficiently managing parking spaces. Furthermore, the paper provides a novel concept of a centralised ISC to update the IS and accept payments to reserve parking spaces for vehicles. The proposed system addresses the concern regarding the wastage of parking space, which is primarily the result of driver unawareness of available parking zones and related parking policies.

Future analysis, which the authors intend to perform, entails enhancing the existing work by formalising and implementing it.

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