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APPLICATION OF RFID TECHNOLOGY AND CLOUD COMPUTING IN CAR PARK MANAGEMENT SYSTEM

The purpose of this paper is to present the idea of using cloud computing and RFID identification system in a car park. The presented system is able to navigate a vehicle to a parking space in the shortest time and to reduce traffic jams thanks to RFID transponders built in parking spaces. The system uses a combination of autonomous and master control to navigate the vehicles. It can execute different traffic scenarios depending on the availability of park spaces and navigate each vehicle using an autonomous route. A dedicated software algorithm for the navigation was also proposed and developed. The system utilizes an external cloud-based database of RFID transponders. A prototype model of car park equipped with RFID technology was designed and built to demonstrate the presented idea.

KEYWORDS: RFID, cloud computing, intelligent car park.

1. INTRODUCTION

Increasing requirements of level of security, integrity and authenticity of electronically transmitted data in automatic identification processes, as well as reduction of operation costs of various public facilities and special applications, have resulted in rapid development of numerous methods of contact and contactless identification of objects. The identifiers are currently used in various processes of automatic identification of objects. Depending on the purpose and the price of entire system, they are implemented in the form of bar codes, biometric elements, magnetic cards, microprocessor and memory chip cards, or increasingly - RFID transponders (Radio-frequency identification). Continuous reduction of manufacturing costs of RFID transponders and standardization of working conditions of radio identification elements create a wide range of applications in security systems and access control.

The design and implementation of a system that will ensure reliable and secure identification of moving objects in the field of transport and road traffic, while enabling its simultaneous tracking in real time is conditioned by legal regulations that refer to automatic vehicle identification AVI [1]. These regula-

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tions [2-5] cover the interrogation zone of single and multiple RFID systems that operate in terrestrial mobile radio networks and such use may not require any special permission [6].

In the era of intensive development of road and motorway networks with increasing volume of transport and road traffic, there is a justified need to control and manage this traffic, and in the longer term - a need to register vehicles having access to protected areas. The needs arise from the fact of intensive establishment of distinct areas of controlled access, i.e. parts of cities, parking areas etc. available only for public transport or special zones (e.g. historic zones) available only for a selected group of rescue or technical vehicles.

The major goal of any identification system dedicated to AVI processes is selection and implementation of a system that will ensure objective and reliable, static and dynamic identification of vehicles, enabling their simultaneous tracking in real time. The formulated assumptions indicate necessity of using contactless identification technology, which will be used for vehicle marking and for conducting of automatic identification, both by means of handheld readers and stationary Read/Write Device (RWD). The implemented activities should be consistent with the essence and legal regulations that apply to the processes of automatic identification of AVI vehicles in the area of transport and road traffic.

2. CONCEPT OF RFID CONTROLLED PARKING SYSTEM

As described above, the RFID system can be used as a car park management system. The purpose of using RFID technology is to propose a solution that is simple and reliable. User does not need to have any parking tickets or mobile apps that rely on internet access. The only condition is to equip every vehicle with a RFID RWD [7].

In the presented concept, the parking area is a building with one way drive on which vehicle is moving to its reserved parking space (Fig. 1). In this solution, all data for car park management can be stored on an external storage in a computing cloud, or locally in the car park management unit. Flexibility will allow to modify the system for unique parking solutions and adjust the solution to many variations of parking areas.

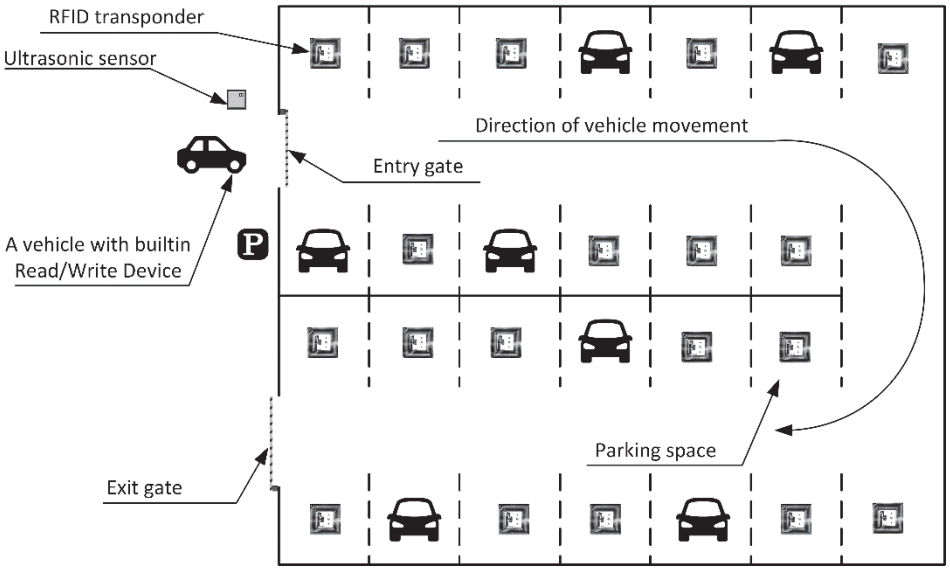

Fig. 1. A concept of car park management system

The key component of the car park management system in a dedicated RFID system structure. It consists of Read/Write Devices installed in vehicles, transponders that mark every parking space and a way in a parking area with Unique IDentifiers (UIDs) [8, 9]. Such structure makes the system more flexible and reliable [10, 11] than other systems that use tickets or mobile apps and can guide the vehicle to the free parking space almost automatically.

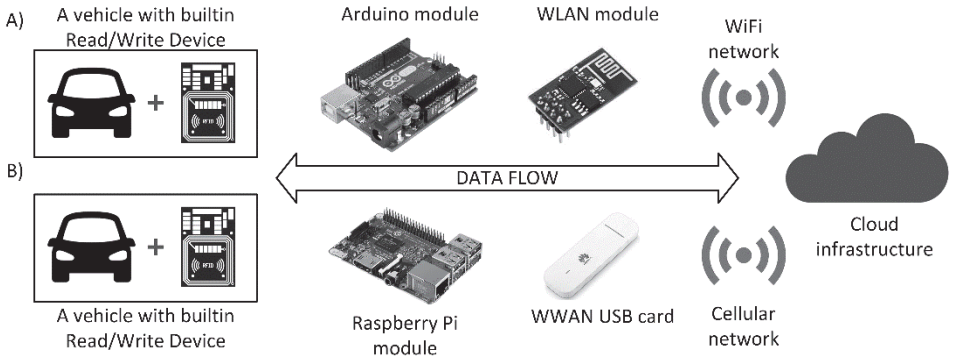

Fig. 2. Stages of communication between vehicle and cloud infrastructure

The central management unit of the parking system is a computer running a dedicated application that manages traffic, performs assignment of free car park

spaces and communicates with the database. As seen in Fig. 2, a single-board computer such as Raspberry Pi or Arduino can be used for this purpose to reduce costs. The crucial component executed by the computer is a park control algorithm written in SFC language of CPDev programming environment [12,13]. The database stores UIDs of every RFID transponder located in the parking spaces and statuses of the spaces (occupied/empty). The database can be hosted either in a private or in a public cloud, similarly as in the vehicle management solution described in [14].

There is also a possibility to move the application to a cloud-based service that will act as the central management unit of the car park system. Therefore, implementation of the dedicated device will no longer be needed, as shown in Fig. 3. The only condition for such approach is a reliable internet access [15, 16].

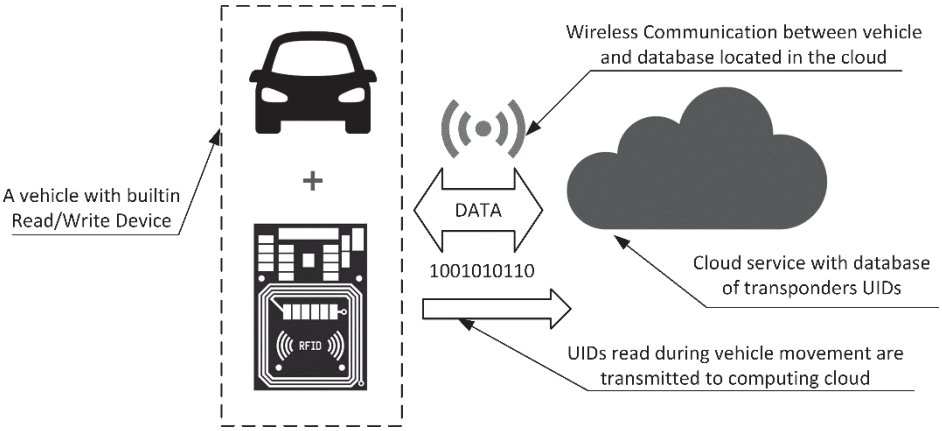

Fig. 3. Direct communication between a car and the cloud infrastructure

3. IMPLEMENTATION OF THE RFID-BASED CAR PARK

The car parking process takes place in the following steps. A driver arrives at the entry gate of the car park (Fig. 1) and stops the vehicle near the gate. The number of free parking spaces available is shown above the gate on a LCD display. The identification starts when the system detects the vehicle at the gate. The presence of the vehicle can be detected in many ways. In this solution it is done using an ultrasonic sensor mounted next to the entry gate. When a car is detected, the Read/Write Device installed in the vehicle reads data from HF RFID transponder installed at the entry gate. The tag contains a connection string which allows the vehicle to connect to the car park management system. Immediately after receiving the data, the vehicle starts communication with the management system through Bluetooth or Wi-Fi. The car sends a request for a free space (Fig. 4).

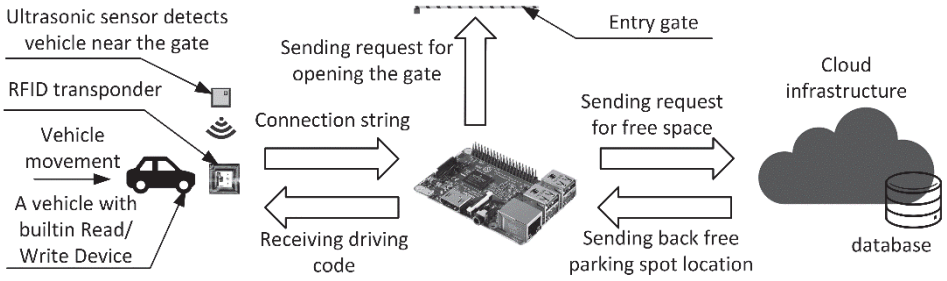

Fig. 4. Management system data transfer diagram.

The management unit receives the request from the vehicle. In the next step, it forwards the request for free space to the cloud service. The cloud analyzes the database to check if there is a free parking space. The system describes the entire car park as two-dimensional matrix holding three possible values – "0","1" and "2" depending on the parking size and structure. The value "0" means that the parking space (slot) is free and can be taken, "1" marks the parking slot as occupied and "2" denotes the route to the parking space. The free parking space is determined using a policy to find the free space as close to the entry gate as possible (Fig. 5).

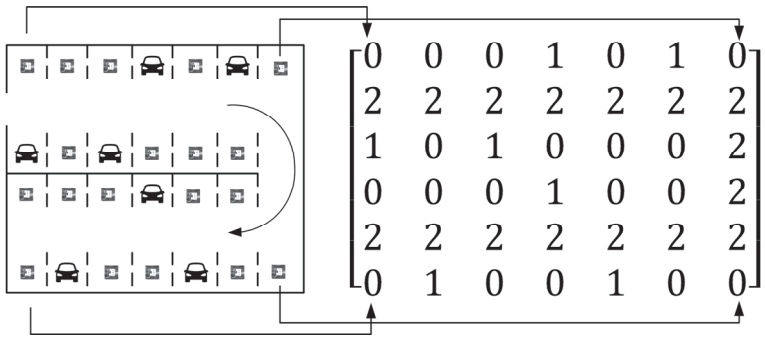

Fig. 5. Two-dimensional matrix visualizing free and occupied spaces in car park example

Once the algorithm finds a free parking slot, it reserves the slot and sends information back to the management unit. If an unexpected error occurs or the connection between the management unit and the cloud cannot be established the parking management is performed using the local database and after the connection goes back online, the local database is synchronized with the cloud.

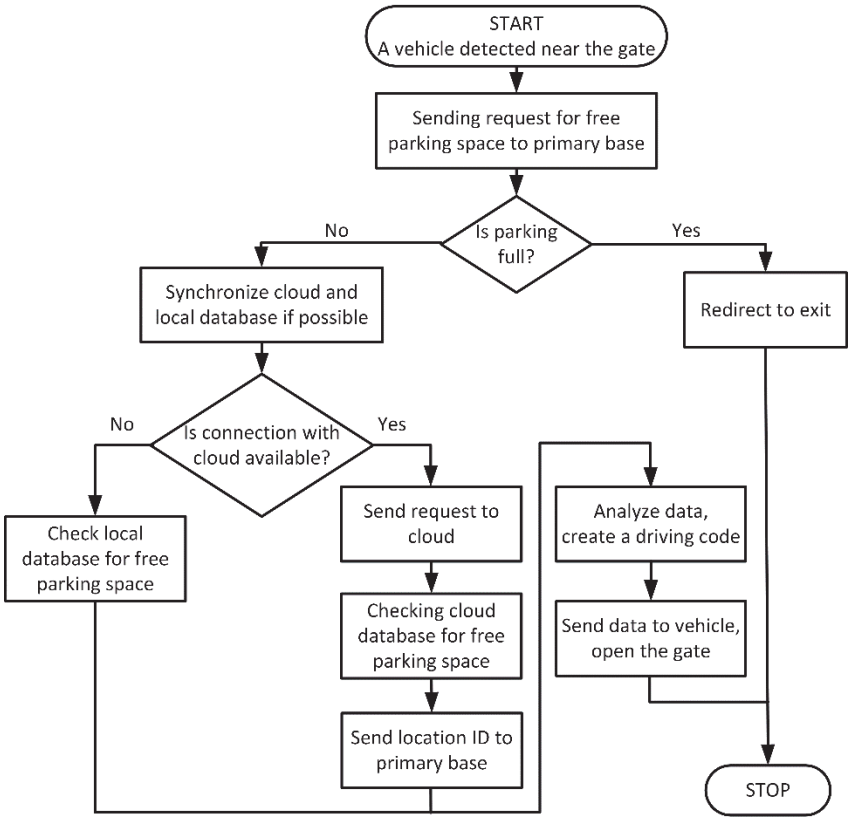

Fig. 6. Car park management algorithm

After the management unit receives the free slot data from the cloud it sends a permission with a driving code to the car, opens the gate and saves a time stamp with identification code of the parking space in the database. The parking system informs the driver about the parking slot number using the LCD display. If the parking area is full, the vehicle is automatically redirected to exit. The algorithm of the solution is shown in Fig 6.

The connection with management unit is a security level to avoid situation that an unknown object is detected by the ultrasonic sensor. In case of a properly-equipped vehicle, the gate will be automatically opened (Fig. 7a). In another scenario (Fig. 7b), the gate will remain closed.

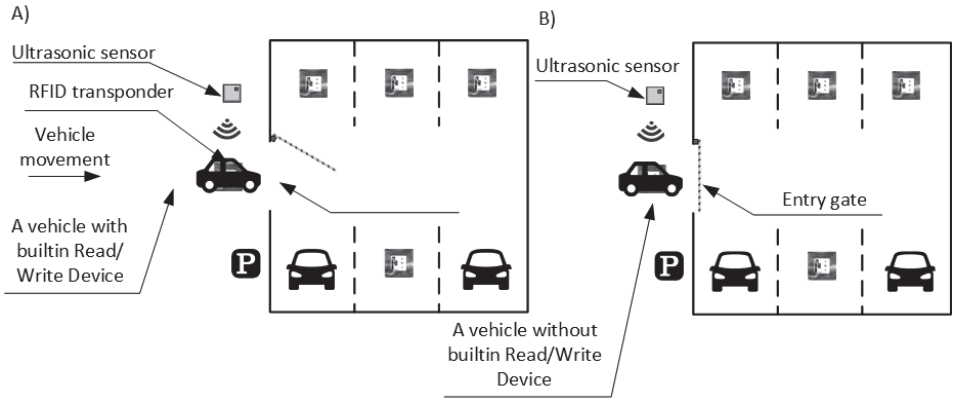

Fig. 7. Vehicle detection a) vehicle with built in RWD, b) vehicle without RWD

After receiving the driving code with a parking slot assigned, the driver drives the vehicle to its destination point. The received driving code contains the transponder UID of the assigned slot and a guidance matrix that will help the driver to reach the point. The guidance matrix contains numbers from "0" to "4" (Fig. 8). The value "0" marks the starting point (entry gate).

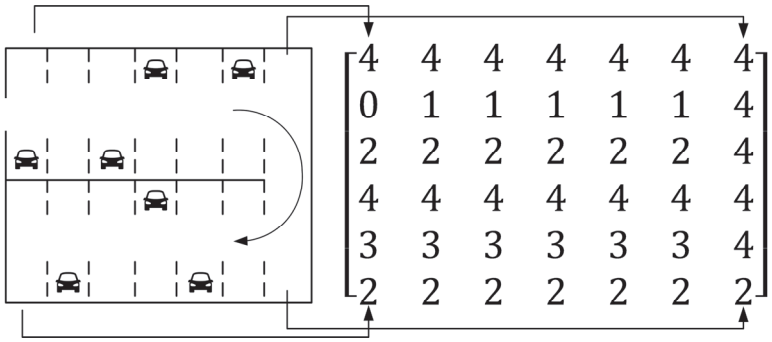

Fig. 8. Two-dimensional matrix representing driving directions

Each number in the matrix represents a direction in which a driver will have to drive to reach the destination point. The value "1" is for going right (in terms of Fig. 8), "2" for going up, "3" for left and "4" is driving down.

In the control program, the guidance matrix is implemented as two-dimensional table with the size of *[x*y]*. In the example shown in Fig. 9, the parking slot with indices [2][2] is chosen for the vehicle. Earlier, the slot is checked in the occupancy matrix from Fig. 5. If the slot is available ("0" at [2][2]), the value "0" is changed to "1" (occupied/reserved).

y/x	0	1	2	3	4	5	6
0	4	4	4	4	4	4	4
1	0	1	1	1	1	1	4
2	2	2	2	2	2	2	4
3	4	4	4	4	4	4	4
4	3	3	3	3	3	3	3
5	2	2	2	2	2	2	2

Fig. 9. Parking guidance matrix with the assigned slot

A special navigation system is involved to guide the car. The idea is to light up a route from the entry gate to the final destination, i.e. the assigned parking slot. LED diodes can be mounted into the road surface or overhead in the garage depending on the car park structure. While the car moves to its parking slot, it crosses RFID transponders installed on the road. The vehicle is reading the UID identifiers RFID transponders and compares them with UIDs in the car park matrix.

Once the car reaches its parking space, the RWD device reads the UID from the transponder and checks if it is the parking slot assigned. If so, the UID code is then send to the management unit to inform that the vehicle has reached its destination. Another record with a time stamp is added to the primary database to confirm that the vehicle has been parked. Starting from that moment, the driver is charged for parking.

When the driver wants to leave the car park, the following happens. Similarly as before, the driving matrix guides the car from the parking slot to the exit point. After the exit gate is reached, the UID of the transponder located there is read. It is then stored with a time stamp in the primary database to inform that the car is leaving the parking area. Once the management unit receives the data, it sends request to open the gate and the car can leave the parking area.

It is assumed here, that there is an additional external system for financial transactions. The driver is billed according to the time stamps stored in the database. The cost is calculated as a difference between time the car reaches its parking slot and the time it leaves the parking area. Since the time stamps are exact, this method charges the driver for the time the car actually occupies the car park with accuracy of one minute, and not of an hour like it is usually done in parking areas.

4. CONCLUSION

Fully managed car parking systems are not common. There are many solutions for management of parking areas but most of them are based on very typi-

cal and simple solutions such as ultrasonic or ambient light sensors mounted on the ceiling. RFID and cloud technology combined together can provide modern, automated solutions. It is possible to create a system with no interference from the drivers and that means fully automated. In terms of smart cities, the cloud-based solution will allow to precisely monitor occupation of municipal car parks and direct a vehicle in advance to the one with a vacant slot.

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