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Low Cost Identification Applications in Traffic Vehicular Environments

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1. Introduction

The world is becoming wireless. In contrast with wired technologies, wireless technologies are widespread in several sectors and they are more and more present in many aspects of life. Wireless includes any technologies which uses no wire. They can be applied for specific applications and have been standardized. (Bluetooth or IEEE 802.15.1, WiFi or IEEE 802.11, ZigBee or IEEE 802.15.4, RFID standardized as ISO 18000, etc).

One of the most valuable reasons for the growth of wireless technologies for communications is the requirements for the mobility of modern applications. These requirements, and also security, make wireless technologies one of the best candidates for these applications and for establishing secure communications in traffic vehicular environments, so for vehicle to vehicle (V2V) as well as for vehicle to infrastructure (V2I).

Electronic Registration and Identification (ERI) of vehicles is a way to identify a vehicle univocally by means of some kind of wireless technology for communication. This protocol allows a wide range of interesting ITS applications, which involves secure identification of vehicles using symmetrical and asymmetrical techniques. These applications could be applied in private and public services (tolling systems, access to parking lots, information services, etc).

Figure 1 shows a schema which explains the whole architecture in order to understand how ERI standards are settled within an AVI/AEI architecture proposed in ISO 14814.

A specific application programming interface of wireless communications developed for Electronic Registration of Vehicles is explained in this chapter as an example of application of this technology. The philosophy of this concept is gathered in the ISO/TS 24534 and ISO/TS 24535 standards, also named ERI standards. This family of standards establishes the architecture of reference to Vehicle Identification independently of the physical technology used, so they do not specify a particular wireless technology to develop any kind of system application (the standard just suggests DSRC technology for deployment of the protocol). In other terms, these standards are linked to the Automatic Vehicle Identification (AVI/AEI) family of standards, which are ISO 14814 to 14816. This family of standards is the framework in which ERI is included.

Taking into account what is explained in the standards, ERI protocol allows establishing secure communications between the road infrastructure and the moving vehicles. This is an issue in which several Traffic administrations have been interested in. In this sense,

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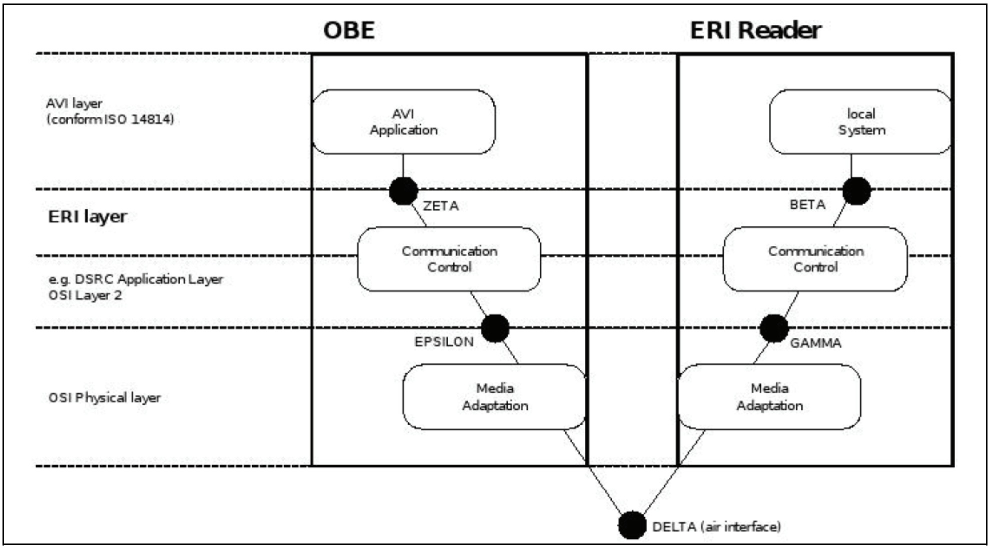

Fig. 1. ERI within the AVI/AEI reference architecture framework.

many countries have developed projects related to electronic identification of vehicles (some of them have taken into account feasibility studies for national or international application, e.g. EVI by ERTICO). Some of these projects are related to electronic plate (e-Plate), like the ones developed in Canada and United Kingdom. In the state of the art of this study, have been analysed some of these projects which show the administrations interests to study the requirements, costs and benefits of this kind of systems in order to implement identification systems for vehicles that serve as a proof of their identity, mainly for legal purposes.

The content of this chapter will be developed as follows. Firstly, a State of the Art of the applications developed in a worldwide framework will be outlined. After this, a summary of the ERI standards and the architecture of our application for several technologies (RFID, Bluetooth and WiFi) will be explained. Finally, the tests made on the developed system will be explained and the results for each one of these tests will be analysed.

2. State of the art of electronic vehicle identification systems

The study of the projects and initiatives in a worldwide context helps to determine the technological needs of EVI systems and serves to find out about the way in which problems have been solved in each application of the identification technology.

The main reference project studied within this state of the art was the EVI project [ERTICO_D2], [ERTICO_D3], [ERTICO_D4], coordinated by ERTICO and funded by DGTREN. The main aim of this project was the assessment of the decision makers in the European Comission and Member States to contribute to the establishment of a European Electronic Vehicle Identification system.

Other projects which have been studied were:

- EVI project was funded by DGTREN and coordinated by ERTICO. This project analysed the requirements for a Pan-European system for electronic vehicle identification. [Inno_Report, 2007]

- RFID within VIKING Euror-regional Project was based in EVI project by ERTICO, and studied the suitability of passive UHF RFID tags for monitoring applications. This project finished in 2004.
- e-Plate project in the UK and Canada which made an implementation of RFID system for vehicle identification. The project began in 2004 and finished in 2006.
- In Japan, there are some related projects for smart plates using DSRC and RFID [SMART_PLATE].

All these projects plot a worldwide sample of the development of electronic identification for vehicles.

2.1 EVI by ERTICO

The EVI project was an initiative of the European Commission, coordinated by ERTICO and funded by DGTREN to make a viability study for a Pan-European system for Electronic Vehicle Identification. This study aimed to identify and evaluate the main technical and non-technical issues for deployment, considering legal issues, institutional, operational and socio-political aspects.
This project has established framework architecture for an electronic vehicle identification system. Figure 2 shows a graphic of components of the EVI system.

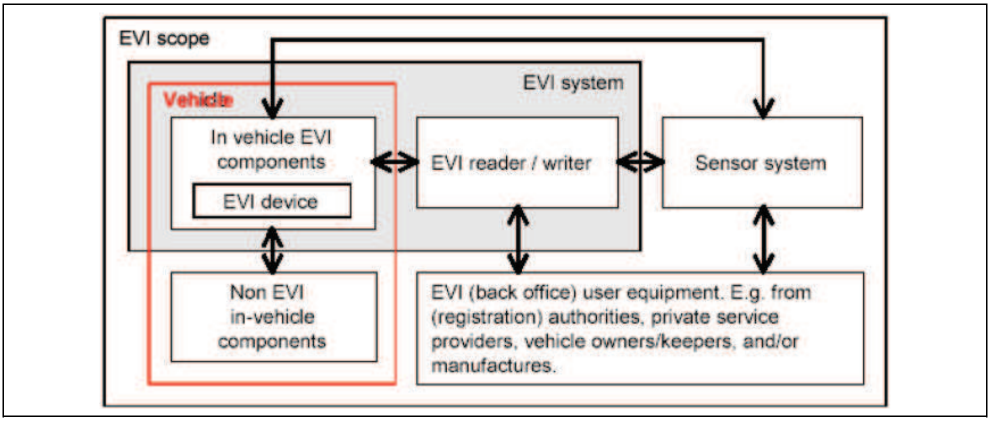

Fig. 2. Schema of components in the EVI scope

EVI system is composed by on-board vehicle components (sensor system, EVI and non-EVI in-vehicle components) and reader and/or external writers. Reader and/or writers are used to interchange EVI information with the different components on-board, they are used by registration authorities, private service providers, vehicle owners and manufacturers.

2.2 RFID from VIKING

In 2004, the Euro-regional project VIKING (Finland) developed an activity related to traffic monitoring using RFID technology called "Suitability of passive RFID tags for monitoring". This project was aimed to study the use of passive RFID technology for road monitoring. The study concluded that passive RFID tags in the UHF band (ISO 18000-6) were useful for traffic monitoring applications.

2.3 e-Plate

e-Plate is a plate with an on-board chip which transmits a unique identifier for each vehicle. A small detector 'reads' the encrypted information and the output of the detector can be used locally or to transmit the encrypted message to a remote host. It was developed by Hills Numberplates Ltd in Birmingham – UK.

This project was initiated in 2004 by the British Government. It used active RFID technology embedded in the plate for the automatic identification of vehicles in the country. This project was developed and validated with trials during three years. Each e-Plate has an embedded tag with an encrypted (128 bits) and unique identifier number, which is transmitted by the tag and is detected by the RFID reader. The system allows simultaneous readings of multiple tags.

Fig. 3. RFID tag by Hill Numberplates Ltd and e-Plate reader by i-Port

2.4 Smart License Plate in Japan

A Smart License Plate is an automobile license plate equipped with an IC chip that stores information such as a license number and car specifications. A Smart Plate communicates with roadside units (antennas) to inform what type of vehicle is passing. [SMART_PLATE]

In 2000, the Ministry of Land, Infrastructures and Transport (MLIT) began the activity of a committee to study a system based on electronic plates (smart plates). These experiments were done thinking of a future commercialization of these smarts plates to gather information of private vehicles. In the textile district of Chojamachi in Nagoya, a trial to test the system was developed. In this district, a system for parking booking by using smart plates was adopted and it gave priority to freight goods vehicles in loading areas out of the road and on the road as parking spaces. It was concluded that the system improved the flux of freight goods. In the same way, vehicles with smart plates were firstly tested in the Japanese streets for a verification experiment.

In January 2006, the MLIT considered Smart License Plates development and commercialization using RFID technology. The embedded chip in the plates has information about the number plate, type of vehicle, etc. These systems were expected to solve traffic jams and to increase security allowing routing or re-routing to specific locations by using antennas installed on the road, etc. In April 2006, a pilot of the electronic plate system was deployed in several taxis of Chiba city.

3. ERI standards

ISO 24534 and 24535 [ERI_1], [ERI_2], [ERI_3], [ERI_4], [ERI_5], [ERI_BAS] describe all the required information for the establishment of identification and registration of vehicles by means of secure communications between vehicle and infrastructure. These standards describe the protocol for Electronic Registration and Identification. The first one is organised in 5 parts which establish the architecture of the system by means of the specification of its parts: ERT (tag) and ERR (reader). It also specifies the requirements of the system, establish operational parameters, defines functionalities, describes a data model and defines two security modes: by using symmetrical techniques and by using asymmetrical techniques.
Figure 1 shows a graph which represents the architecture of AVI/AEI (Automatic Vehicle Identification), where the ERI layer which allows communication and control capacities can be distinguished.
Figure 4 shows the different streams which both standards can define for different applications. The parts of the standard implemented are shown in orange colour. In the implementation of this standard some developments have been made in the AVI and ERI layers and the control and communication sublayer.

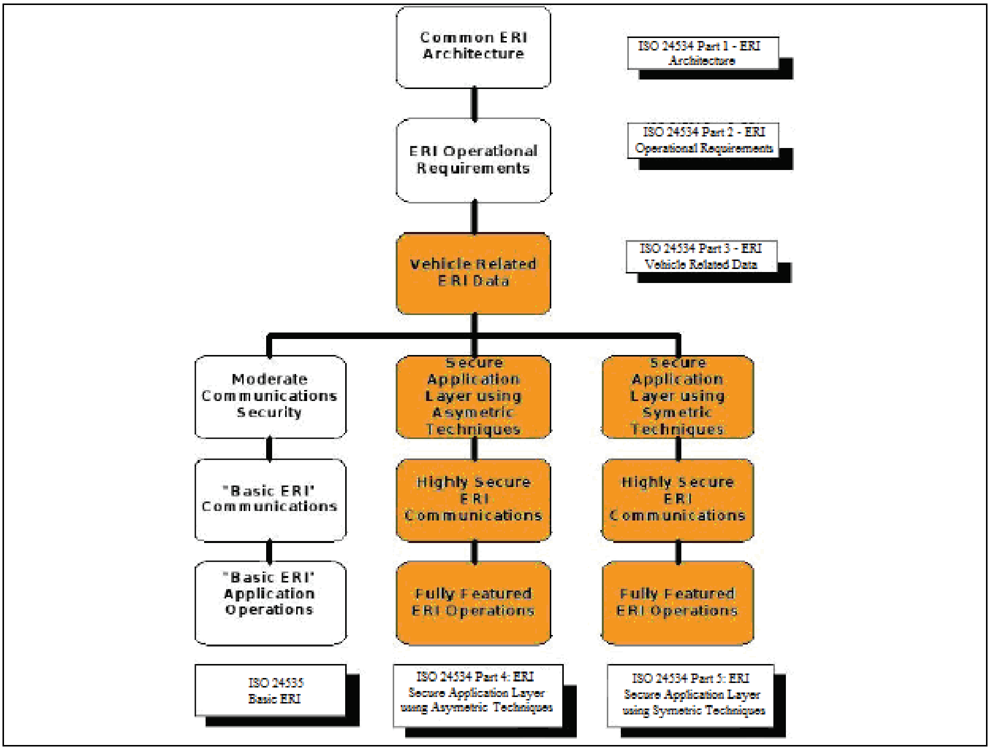

Fig. 4. Functional pile of the ERI system (includes different standards)

The protocol was implemented for each application scenario, originally planned as a set of messages to be used in each application and sequence. In order to apply the protocol, the ERI standards suggest DSRC technology, but several wireless technologies more and their

associated standards have also been studied to be used in this implementation, such as WiFi (802.11 b/g), Bluetooth (802.15.1), RFID (ISO 18000-4), ZigBee (802.15.4) and others.
Figure 5 shows a layered representation of this implementation. This implementation was made in Java, using J2ME for mobile devices on-board the vehicle (PDA) and J2SE for devices in the infrastructure (fixed and outside the vehicle).

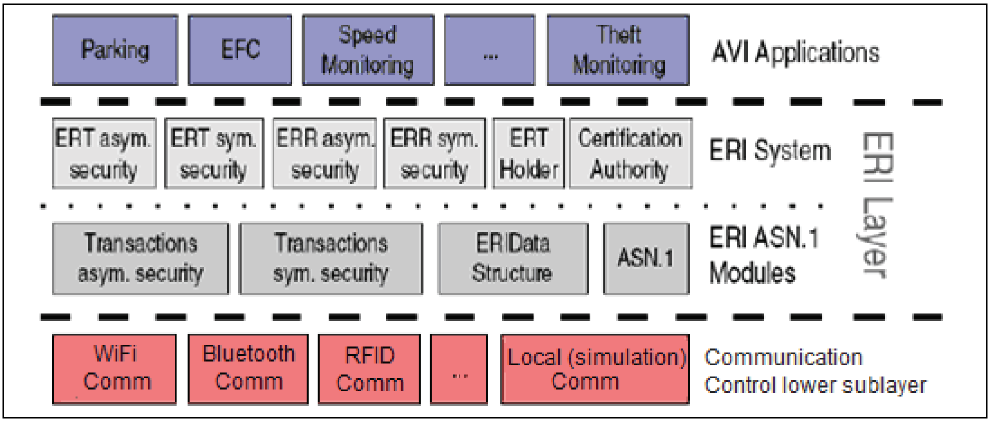

Fig. 5. View of the layered structure of the implemented software

3.1 AVI application layer

In the AVI application layer, several simple applications were implemented, which made use of the ERI functions. This layer was oriented to allow the implementation of the tests for the ERI protocol in different conditions.

3.2 ERI layer

The ERI layer as a two-layered structure has been implemented. The lower sub-layer is the layer for the ASN.1 modules as described in the ISO 24534-3 and 4 [ERI_3], [ERI_4] which is based on the ASN.1 vocabulary and transactions. The upper sub-layer implements the functionalities described in the standard [ERI_5], defining the actors in an electronic registration scenario: ERT (tag or device which stores identification data for the vehicle), ERT Holder (device used to access the owner of the tag locally), ERR (reader or device which allows remote access to the ERT for the service providers or authorities) and CA (certification authorities which generate and manage ERI certificates for remote secure connections).

3.3 Communication and control layer

This layer allows the wireless communications (by Bluetooth, WiFi, RFID) and local communications for simulation purposes.
Figure 6 shows the logical relationships which each module establish with each actor within the whole ERI system. The different colours indicate the different virtual machine which controls the module. The yellow modules are designated to J2ME devices and the orange ones are designed to run in backend service, therefore they work on J2SE, although they are J2ME compatibles.

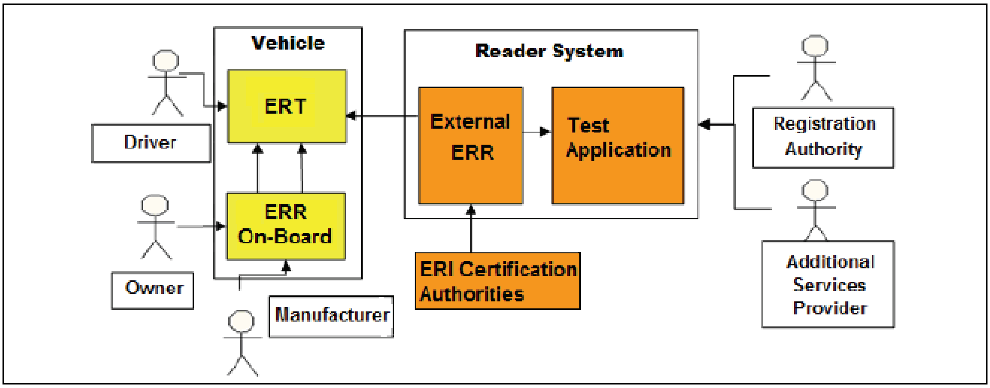

Fig. 6. Schema of the identification system.

Each one of the five parts of the logical system has its functionalities. The description of each logical part is as follows:

- ERT Module (Electronic Registration Tag): it is the Tag installed in the PDA. It has some classes to provide several functionalities and an interface to show data.
- ERT Holder Module: it is in charge of the local tag reading inside the car.
- ERR Module (Electronic Registration Reader): it is in charge of external readings, or any other operation programmed over the tags in the zone.
- Test Application Module: it receives data coming from the reader and makes a data process. It is for demonstrations.
- Certification Authorities: it is the system to generate certificates for security matters.

4. Test of the system

In order to test the API developed for Electronic Registration and Identification, several applications were developed. The tests for these applications have taken into account the range of velocity, distance and the inquiry time.

The communication staffs used in the tests were:

- WiFi router (802.11 b/g) and a pigtail
- Bluetooth dongle (802.15.1) and a pigtail
- RFID reader and 3 RFID tags (ISO 18000-4) at 2.45 GHz
- Patch panel antenna at 2.45 GHz for using with all technologies considered
- PDA containing ERI applications, which is used as ERT
- PC used as ERR with back-office applications (for monitoring the system)

The characterization of the test antenna was done at the anechoic chamber at the University of Valencia. Figure 7 shows a photo of the measurement process.

The measurement of this antenna was made by using the method of two antennas for the measurement of the antenna gain. Figure 6 shows the results for horizontal and vertical polarization.

The communication zone for the wireless technologies between tag and reader was also determined in an outdoor urban site for each one of the technologies used. All of them use the same frequency band at 2.45 GHz, so the covering area of the test antenna has been measured. Figure 7 shows a plot of the power density distributed in the test area.

Fig. 7. Antenna for the reader in the Electromagnetic Anechoic Chamber at the University of Valencia.

Taking into account reading distance and velocity, the EVI applications implemented present different profiles according to ISO 24534-2 [ERI_2]. The applications used:

- Theft vehicles control: static readings and at short distances. The profiles used are ERT-D6 for the velocity and ERT-C7 to C9 reading distance.
- Parking access control: static readings or with low velocity (less than 20 km/h) and at medium distances. The profiles used are ERT-D5 the velocity (the velocity for accessing a parking lot should not be greater than 25 km/h) and ERT-C6 to C9 (distance under 10 metres).
- Average velocity control: dynamic readings (different ranges of measurements) and variable distances.

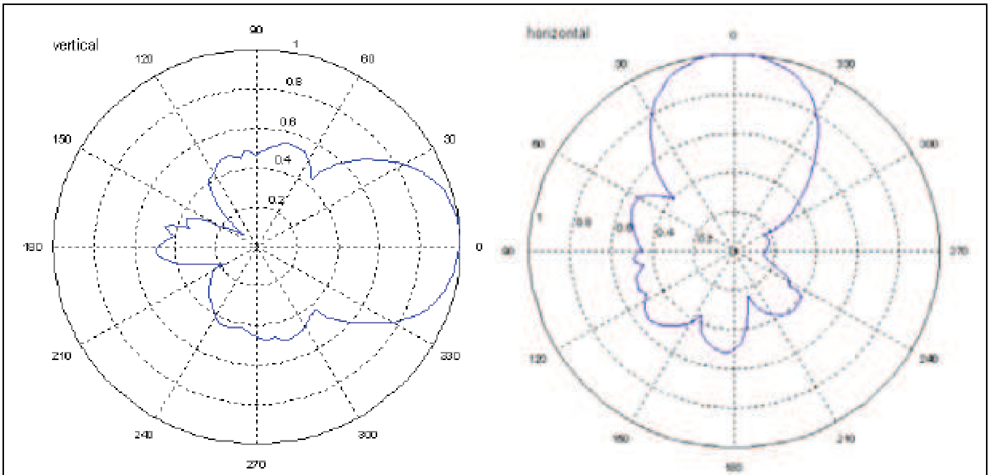

Fig. 8. Radiation pattern for the test antenna in horizontal and vertical polarization.

Tests with the vehicle in movement allowed testing within the communication zone. Communication between tag (inside the vehicle) and the reader was established. (located at the Institute of Robotics).
The tests were made at three communication distances: at 10 metres from the reader antenna (black point), at 22 metres (green point) and at 45 metres (white point). Also several velocities were used: 20 km/h, 40 km/h and 60 km/h (due to velocity limitations in the urban circuit). Figure 9 shows the communication area for the tests.

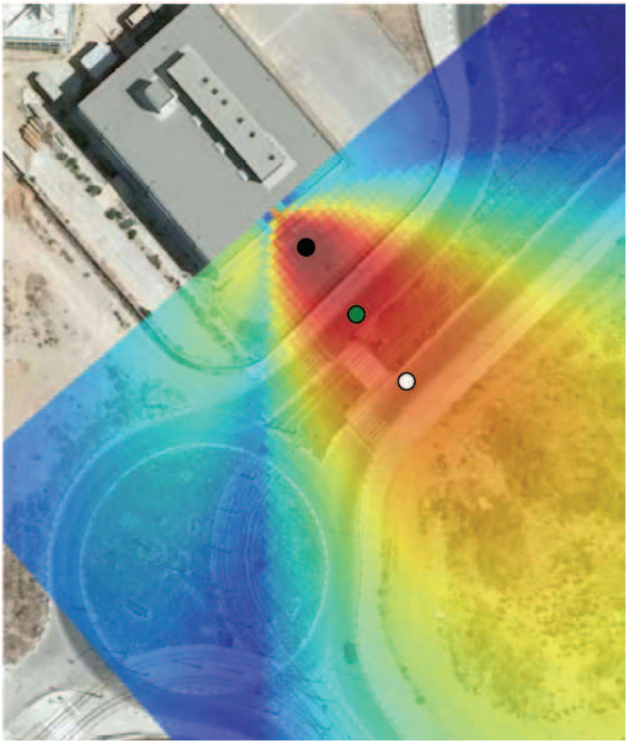

Fig. 9. Power distribution within the communication zone in the test area.

Figure 10 shows a capture of the data transmitted, processed and collected by the reader. The interchanged information is extracted from the ISO 24534-3. The information sent to the ERR was PDU, vehicle ID, chassis number, brand, model and colour of the vehicle.

4.1 Test of applications with WiFi

The applications tested for WiFi technology [802_11] has showed good results in the readings between tag and reader. Each application has been launched and transaction times have been measured with the reader. In accord with other authors, measurements have shown that the discovery time for WiFi is higher [Pering, 2005] than in Bluetooth technology. Figure 11 shows a histogram with these results. Also table 2 shows a summary of the test results for the ERI applications using WiFi technology at different distances and velocities.

```
Initializing
ERR: EriData created
Waiting for connection
Connection stablished from: /147.156.222.234:5555
ERR : initiated GetEriData
ERR : Sent PDU = 64 1 1 -128 1 64 108 101 99 116 111 114 65 49 4 78 106 -48
123 -128
ERR : Received PDU
*************************--ERI DATA--*******************************
** VIN = VS6DW990LK000007
** CHASSIS NUMBER = X500-100-24-7566-A-6454
** BRAND  = RENAULT
** MODEL = 19 XN
** COLOUR = RED
*******************************************************************
```

Fig. 10. Data transmitted and collected by the reader.

	20 km/h	40 km/h	60 km/h
22 m	Works	Works	Some errors in transactions
45 m	Works	Works	Some errors in transactions

Table 2. ERI tests with WiFi

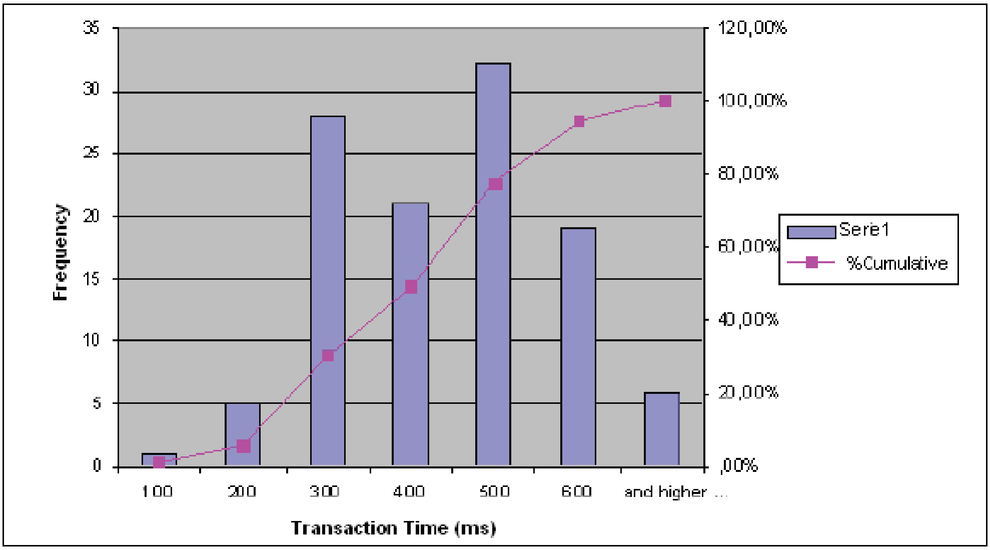

Fig. 11. Histogram with transaction times for WiFi technology.

4.2 Test of applications with Bluetooth

The applications using Bluetooth technology [802_15_1] have also given good results in the readings. Although Bluetooth devices have higher discovery times (between 10 and 40 seconds) than WiFi technology, the transaction times are lower [Pering, 2005] [Jiang, 2004].
Table 3 shows a summary of the tests results for the ERI applications at different distances and velocities.

	20 km/h	40 km/h	60 km/h
22 m	Works	Works	Some errors in transactions
45 m	Works	Works	Some errors in transactions

Table 3. ERI tests with Bluetooth

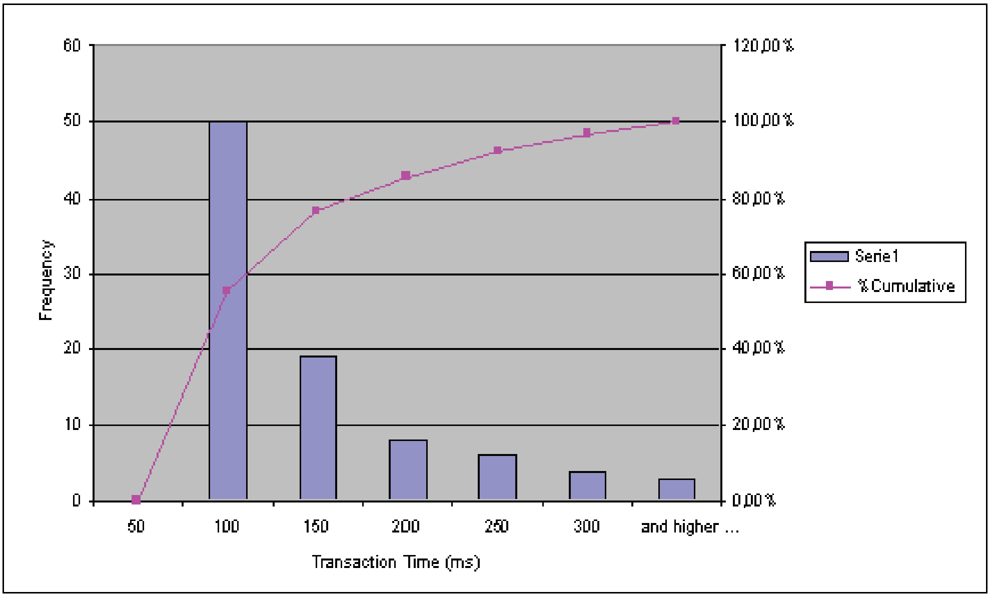

Fig. 12. Histogram with transaction times for Bluetooth technology.

4.3 Test of application with RFID

The RFID technology has limitations regarding the quantity of information to be sent in the communication between tag and reader. It also has limitations regarding security. For these reasons the implementation of the standard, can only be done with the ISO 24535. [RFID_4]
Table 4 shows a summary of the tests results for the RFID technology with the ERI applications at different distances and speeds.

	20 km/h	40 km/h	60 km/h
22 m	Works	Works	Works
45 m	Works	Works	Works

Table 4. ERI tests with RFID

5. Conclusions

This work has produced an API for the development of applications for Electronic Registration and Identification of vehicles has been implemented. This API has been published under GNU/GPL license. (API and documentation can be downloaded from http://smagris3.uv.es/preri).

Several applications for test have also been implemented. Three wireless technologies (WiFi, Bluetooth and RFID) have been proposed. These applications have been installed on the PDA and have been tested in a road next to the Institute of Robotics at the University of Valencia.

The tests of the developed applications have showed that [Segura, 2008]:

- The used technologies are valid for the applications implemented for slow uses (up to 60 kph).
- The discovery time in Bluetooth devices is too high (between 10 and 40 seconds) for dynamic applications.
- WiFi has problems in the discovery process through SSID due to the fact that it is not implemented in the version used of the J2ME. In the tests a fixed private range of IPs was used to simulate this behaviour; however it would present problems in a real implementation.
- WiFi and Bluetooth had high error taxes in the communication for velocities higher than 60 km/h. This is not the case for RFID.
- The amount of information to be transmitted in WiFi and Bluetooth applications are higher than in RFID.
- In case of a high humidity (or in a rainy day), the frequency of these three technologies used (2,45 GHz) has a high power attenuation.

6. Future research

This research has allowed establishing a framework to allow programmers to develop applications for electronic registration of vehicles. From the results obtained, this API can be applied to secure communications between vehicle and infrastructure by using asymmetric and symmetric security.

For future research, we are going to finish implementing Basic ERI (as shown in figure 4). We are also going to implement discovery process in WiFi technology by using a new version of the J2ME and assigning a wide range of IPs in order to avoid problems in a real deployment. Other technologies, as ZigBee (802.15.4) or WAVE (802.11p), are going to be implemented and tested.

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