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Development of a demonstrator «smart-parking»

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Abstract -- The main goals of the demonstrator developed within the FRDISI (Foundation for Research, Development and Innovation in Engineering Sciences) in Casablanca (Morocco) are to allow the development of new concepts and tools in smart-parking management. It will also permit to experiment other smart sensors and parking management analysis algorithms. The demonstrator will offer a platform to develop and experiment innovative solutions for an efficient management of the energy consumption of all the infrastructure and physical equipment of the smart-parking.

Through our demonstrator, FRDISI will be able to help drivers, through a web or android application, to reduce parking search time, to make place reservation. This application proposes a lot of innovative functionality among them a reservation system. It will help the parking owners to increase the rotations of their parking spaces (near malls, near airports) which can positively impact the economic profitability of the parking infrastructure. In addition, the demonstrator produces green energy and is energy autonomous. For cities responsible, it proposes steps for the support tools' development in smart-parking and analyze the uses for a better definition of the mobility policy of the city.

FRDISI will launch many subjects in applied research domain to improve and develop the know-how in the field, to develop and experiment innovative futurist solutions such as optimization algorithm in the parking rules according to demand (handicap, drop-off, public transport, funds conveyors, neighborhood markets, schools, events, etc.), implementing new sensor technologies and new modes of energy-efficient communication while taking advantage of existing telecommunication infrastructures (Internet of Things IoT Concept). As our platform will encourage the green mobility solutions by providing smart load for electric vehicles.

Keywords -- *Smart-city, smart-parking, IoT, TIC, WSN, energetic autonomous, solar photovoltaic, security system, parking management algorithm, cloud.*

I. GENERAL INTRODUCTION AND PROJECT CONTEXT

Parking problem is actually one of the major research issues in planification and traffic management of urban transport. With smart cities concept emergence, cities are increasingly using information and communication technologies (ICTs) to improve the quality of urban services while reducing costs. The development of smart-parking is an attractive way for a city that wishes to integrate itself into this smart-city concept. Connectivity plays a major role in this evolution, but also the real time analysis capability of the amount of data by computers.



Figure 1: Demonstrator localization

In the state of art, we can distinguish three main types of smart-parking: indoor, outdoor and on street parking. The complexity of the solution differs depending on the three cases, although it may have some similarities.

The authors of [1] use a network of RFID tags combining with RFIDs' antenna for the detection the occupation status of each parking lot, this solution can be misleading in the case of low sunshine. The authors of [2] propose to use QR-codes as sensors at each place. This solution is too dependent on the good faith of the users. The study [3] proposes the use of ECC (Elliptic Curve Cryptography) to secure the data available in the sensors. This kind of cryptography algorithm represents the best compromise between security and CoAP (Constrain Applications Protocol) constrains. Other studies, [4] for example, use optical sensors such as (infrared) at each place, while others [5] choose image processing to detect vacant spaces.

The choice of sensors for outdoor car parks is tiny difficult. Such installations being subject to all unfavorable conditions for electronics. Article [6] proposes a shared parking model, and a management application to use this kind of installation. It also offers other services like booking, user assistance to the parking.

This paper [7] proposes guidance's algorithm based on four metrics: Driving distance to the proposed parking, walking distance between destination and parking chosen, expected cost, and congestion to the proposed parking. In addition, users can book; obtain an itinerary to his parking slot. Article [8], takes advantage of smart phones by using them as sensors and use crowd sourcing to know the parking occupancy.

The demonstrator described in this paper has been designed to experiment and validate at full-scale innovative solutions implemented by the center's searchers or other partner who

are interested in issues related to parking problems and mobility as part of the smart cities. The figure 1 shows the plane of the smart-parking object of our demonstrator. It is built on an area of approximately 1500 m² and is laid out according to the current standards to offer a capacity of 51 vehicles parking spaces distributed as follows:

- 45 free places for subscribers and non-subscribers,
- 4 places dedicated to the reservation system for subscribers users only,
- 1 space adapted for Persons with Reduced Mobility (RMP),
- 1 space with a charging system for electric vehicles

In addition, the demonstrator is equipped with a set of technical equipment providing it the "smart" label, which is equipped with auxiliaries imposed by regulations and the need for comfort: parking areas for two-wheeled vehicles, sanitary rooms, access for PRM, solar shading, etc.)

This paper is constituted as follows: a summary and an introduction already mentioned. Below, we will describe the material composition (energy component and instrumentation component), the power supply and energy management in the first section. The second section discusses about the demonstrator's management application.

The energy component built on the positive energy building concept. The solar photovoltaic ensures the energy needs of the smart-parking and the overproduction is injected into the internal electrical network of the research Foundation. The optimal energy management and the load of electric vehicles are initiated and included in the research actions to be carried out in the immediate future.

The instrumentation component built around a wireless sensors network, access control systems, infrared cameras and detectors. The demonstrator also offers the possibility to test different types of sensors (wired or wireless) and security systems.

The informatics component built around mobility management algorithms that rely on the exploitation of the Cloud environment. The control tool, which is being developed, is used to control the display of the number of available places or other specific information intended for broadcast on dynamic panels. An intelligent parking reservation and prepayment system through a mobile application (Smartphone, tablet, laptop) is also being finalized to offer new and innovative services to the users.

II. MATERIAL COMPOSITION OF THE DEMONSTRATOR

The figure 2 below shows the demonstrator's general architecture. Its material part is mainly composed by three systems: firstly, the parking management system, secondly, the local signaling system and the last concerns the security system of our demonstrator.

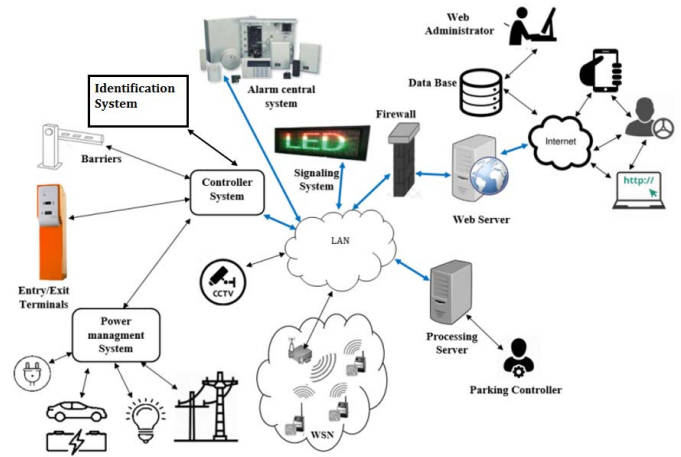


Figure 2: General architecture of demonstrator

A. Parking management system material

This first system is mainly composed by wireless sensors network (WSN). It also integrates entry/ exit terminal coupled with an identification system and controlling automated barriers.

Concerning the WSN of the demonstrator, it comprises, in one hand, the sensors and on the other hand a base station (BS). Each parking place is equipped with a sensor providing the status of the parking lot and other useful information (battery state, number of transmissions, etc.) on the sensor. The sensor determines the state of its parking lot and transmits this information to the BS wirelessly. Then, all these information gatherings by the set of sensors are collected by the BS which transmits them to our processing server. The BS acts like a simple gateway which collects wireless data and transmits them through a local network to the server. The used sensors are optimized to have autonomy up to 7 years depending on the parking average time of the vehicles in the parking lot. Below, an evolution graph according to the average parking time.

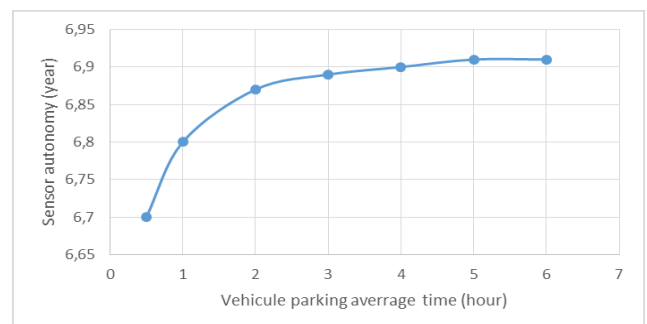


Figure 3: Battery autonomy

The batteries lifetime is almost constant when the vehicle parking average time is more than 5h.

B. Parking signaling system material

Parking availability is indicated locally via the screens and remotely via a web application for mobile. At parking entrance, a car's user can read the display screen to see if there are places available. Indeed, if there isn't, entrance barrier will be remained closed! In case of availability and after authorization process driver enters in the car park, he is assisted by the combination of the ground marking and the

signaling system to help him find a free space. Once the car occupies this place, the detector equipping the place informs its state to the base station. Thanks to the vertical marking, the driver will know the reserved places for the RMP (Reduced Person Mobility) and the places equipped with electric reload unit. This signaling system is commanded by the processing server via a local network.

C. Parking security system material

To ensure safety, each of the aisles of the car park is equipped with cameras observing all inside evenements; those cameras combining whit a set of detectors (fire, flood, presence) and access control system protect also the demonstrator's equipments.

The perimetric protection is also ensured to prevent intrusions. For this purpose, we use a pair of infrared transmitter / receiver and others cameras to monitor each vulnerable segments accessible from the outside.

We also use a firewall to prevent from all unauthorized access to our LAN.

D. Power supply and parking energy management

The approach adopted is part of the dynamic of energy transition [9]. It is consist to develop experimentally and profitable new energy technologies based in particular on:

- The production of renewable energy from photovoltaic panels covering parking shelters;
- The active management of energy demand and consumption of renewable local production and injection of surplus into the internal network of the research center;
- A storage facility to allow the use of electricity from renewable energies at peak consumption times;
- Electric vehicle charging solutions

We evaluated the power requirements of our parking at 3155 W. After estimating the daily operating time of each device, we assessed 34.5 kWh daily consumption of the parking.

Then, we estimated the area of the parking lot to be covered by solar panels in order to produce the necessary energy; which led us to implant 40 solar panels with a unit power of 250 Wp. This corresponds to a total power of 10 kWp occupying a total area of 66 m² (Two shelter modules = 25% of the total area currently covered) (Figure 1) The solar field is connected to the electrical network of the building through a 10 kVA inverter.

E. Evaluation of expected PV energy

We adopted an optimal layout of the panels according to and local sunshine data, the PV production is estimated and approximated to the need. The figure 4 below shows the daily requirements for the expected monthly PV production:

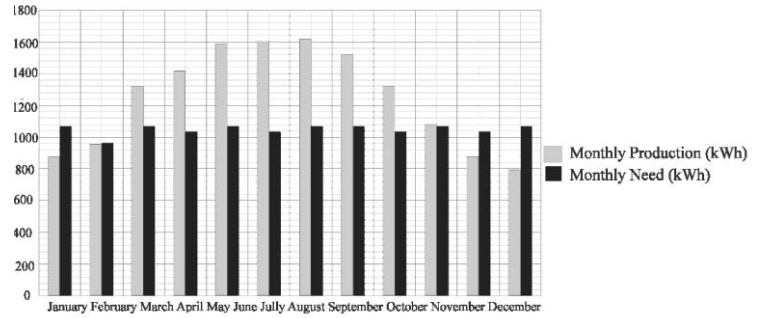


Figure 4: Current PV production and need

The following table gives the average of the energy produced by the PV and consumed by the parking on a day, a month and then a year:

	PV daily Production (kWh)	PV Monthly production (kWh)	Daily energy requirement (kWh)	Monthly energy requirement (kWh)	Daily deviation (kWh)	Monthly deviation (kWh)
Average annual	41,00	1247,70	34,43	1047,25	6,57	200,45
Total annual (MWh)	14,97		12,57		2,41	

Table 1: PV production and parking consumption

It can be seen that the PV field covers the energy requirements of the parking with an annual surplus of 2.41 MWh (about 15%) injected into the building's internal network. Also, it should be noted that during the months of November, December, January and February, the plant needs are slightly higher than solar production. This deficit is taken from the network where the surplus produced is injected the rest of the year.

F. Charging station for electric vehicles, Energy storage and management:

It is planned, in the near future, to cover PV panels of the entire surface of the remaining six shelters. This corresponds to a total production of 40kWp.

Figure5 shows the difference between the energy produced by the 40kWc that will be installed and the overall need for the equipment. The additional power can ensure the power supply of the charging station being studied.

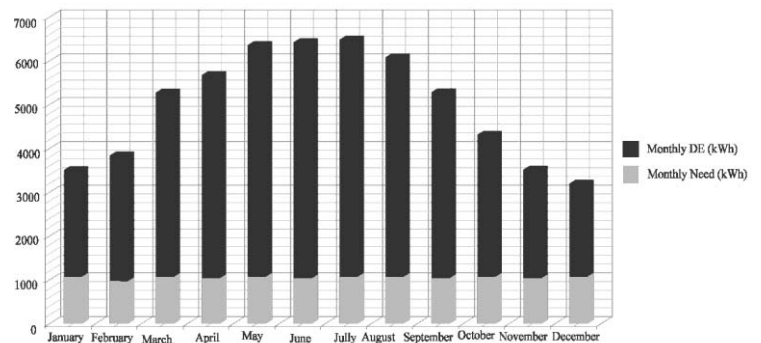


Figure 5: Energy produced by the 40kWc again parking need

In the sizing of this charging station (Power = 3700 W), the lowest power level was used in the year to ensure the battery charging of the electric vehicle even during the most unfavorable periods of sunshine (Table 2) [11].

	Average Daily Power (W)
January	3541,67
February	4375,00
March	5541,67
April	6125,00
May	6541,67
June	6833,33
July	7000,00
August	6541,67
September	5625,00
October	4750,00
November	3741,67
December	3283,33

Table 2: Minimum power used to charge electric vehicle

The integration of energy storage is being studied to allow the development of a flexible and intelligent energy management [10] of the whole research center, already equipped with a solar field of 60 kWp.

III. MANAGEMENT SOFTWARE OF THE DEMONSTRATOR

This software aims to simplify the parking process for all involved, by allowing all parties concerned to communicate with each other and seek the help of the system administrator when it is needed.

The technical architecture proposed is shown in the figure 2. It involves three essential phases: collection phase, processing phase, and consultation phase.

After collecting the parking information from processing server (license plates, entrance and exit times, busy places, etc.), they are stored at the level of a database server to be operated by a web server which communicates with the administrator of the system as well as the drivers via the web application in order to present the offer in real time and other services that will be explained later.

This architecture is mainly based on the following factors:

- **The user:** interacts with the web application; it can carry out several actions such as checking the condition of the parking lot (if there is a place available to park) to reserve it in advance, to present a complaint all after authentication/registration at the level of the web application.
- **The web administrator:** he has visibility on the whole system; he manages the users and must ensure that the database of the application is updated.
- **Parking controller:** It must ensure that the equipments in the parking area work perfectly, that there is no uncontrolled anomalies or an alarm triggered without being examined.

It is to highlight that for users there are mainly two categories:

Subscribers: they use the parking nearly every day, they have a monthly or an annual subscription card. For drivers who take advantage of the services with an average of 7-10 times a month. They have a rechargeable card each time they use the parking the amount is withdrawn from the main balance.

Visitor: A user who consults the application without registering and who uses the parking with payment on the spot.

The common point between these users is that they all benefit from the functionality of the application with different privileges, yet a driver who does not have access to the

application can also use the parking and it will be treated as a visitor when paying.

A. Services

The application allows users to see real-time parking offer, empty / busy places, as well as path to the parking. The user can also interact with the administrator by sending him a complaint or request for information, they can also make the payment of their subscription, consult the price list. All of these and other services are easily accessible at our application level.

In addition to the services mentioned above, we choose to include the reservation of a parking space in advance. This will reduce the time spent looking for a place, emitting CO2 and eliminating the frustration of the drivers that classic parking engenders. It is in this context that we thought to include the reservation option.

To benefit from this service, the driver must be registered at the application level; the reservation is booked by indicating the time of entrance, the time of exit and the car's license plate.

In fact, we distinguish two types of reservations:

- Closed reservation: the user specifies the time of entrance, of exit and he makes the payment online. In this case the place is not lost even if the user does not arrive in the parking lot.

- Opened reservation: the user just specifies the time of entrance and does not make the payment, in this case if the user does not arrive within a predefined time the place is lost.

When the user reserves a place, the administrator checks the availability and sends him a confirmation/ cancellation message.

The reservation system uses the identification system information to perform the required actions. Through identification system the management application can distinguish between vehicle and drivers.

B. Our Application

To make parking information accessible to the users, a web application has been developed that encompasses several services in order to simplify the parking process.

In addition to knowing the number of available places in real time, the application allows the users to have the itinerary of the parking lot from their location, check tariffs, submit a complaint, sign up or sign in to their accounts.

After authentication, the user can make the payment of his subscription, make a reservation or modifies his personal information (this modifications must be approved by the administrator).



Figure 6: Home page of the web application

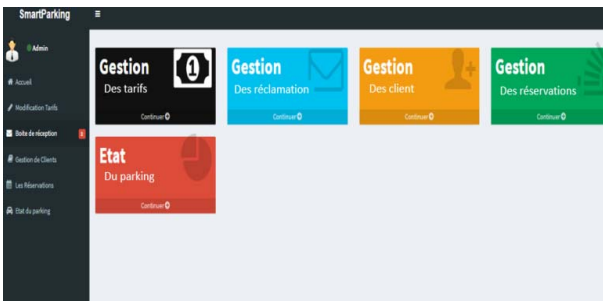


Figure 7: Administrator's Interface

The administrator handles user management, reservations, responds to messages, and he has also a general view on the parking state in real time.

In addition to its functionalities, we opted for a responsive application with a design which facilitates the use on multiple devices (Tablet, computers and mobile phone.).

III. CONCLUSION AND PERSPECTIVES

Through this paper we have given an overview of our demonstrator, rich in research and development opportunities (Algorithms to optimize the parking utilization, an open and extensible platform allowing tests on multiple types of sensors technologies).

Concerning our main contributions:

- Realization of a green Parking (energy autonomy, green energy...)
- Electric charging for electric cars
- Development of an innovative reservation system via a web or android application
- Assure security of goods and people within the parking
- Reduce the walking distance by offering customers the closest parking space

Development perspectives are given for each of the components presented, such as:

- Development of autonomous micro sensors
- Optimization of energy consumption in wireless sensors
- Urban eco conception by multi criteria optimization
- Parking and street parking services and dematerialized management
- Integrated design "sizing / management" by optimization, micro-networks with storage
- Electric recharge from green electricity.

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