Sistema de Gestão de Estacionamentos

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Abstract

Life in the city as several issues, one is the paid parking, witch is all hover the place, acknowledging this, and using the concept of wireless sensor networks we have created a parking management system. The system is build with 3 major elements. The Parquimetro (parking meter) is responsible for the management of a parking area, the SensorCarro, witch is a device placed in cars, and is responsible to determine if the car is or is not parked, finally the Fiscalizador that allows for the verification of the parked cars, if they are following the rules or not. The system is fully autonomous, witch means the clients don’t have to do anything besides parking the cars. This way the system will always work fine, because it isn’t dependent of the will of the clients to collect de parking money.

The system is also capable to determine the localization of the cars in the parking area. This capability allows SensorCarro to pick the nearest Parquimetro so it can manage is parking.

After the realization of some tests, we acknowledge that the system is working like expected, but the localization needs to be improved in future works.

The developed system is our belief that it can be applied in real life, but it needs some specific tests to fully prove that our system will work in the real life.

Key-words: wireless sensor networks, autonomous, parking, localization.

1. Introduction

With this work it was looked to simplify one of the daily tasks in the cities, the payment of the parking. The system removes of the customer all the obligations related with the parking in zones with parking meters. The person proceeds as if she parked in a not paid zone, parks and.

Currently the people need to know the time it will be parked before they pay. The problem is that if it needs more time, has to go to parking meter again. There is another problem, when the paid more time than the necessary.

Beside the previously cited problems we cannot forget that some times are difficult to find one parking meters that function, since these frequent are incapacitated. The parking meters are destroyed for fun or for robbery, other times, they break by itself.

These entire problems result in people not being charged for the parking space and the maintenance costs increase.

To eliminate these problems the use of a system that removes the money of the parking meters becomes imperative. The payment has to be in a form that allows that the parking time is the
difference between the time of leaving and the time of arrival at the parking place, preventing the payment of time that was not used, and the necessity to go to the parking meter to buy more time.

In this way it is necessary to create a system that carries out the management of the parking space on an autonomous way, without the necessity of intervention by the customers.

The implemented system uses wireless communication between the different elements of the system. The system is composed by three elements, the Parking meter (Parking meter), that manages the parking places and count the time spent by each user in the parking, the SensorCarro, whom determines if the vehicle is or is not parked and informs the Parking meter of the beginning and the end of the parking, the third element is the Fiscalizador, this is responsible to make sure that the parked cars are paying for the parking space.

As already said this it is an autonomous system, where the only human being intervention is in the inspection to make sure that the parked cars are paying for the parking space, the remaining tasks of the management of the parking are carried automatically.

A form to implement this system is through a wireless sensor network. This network is composed with a great number of elements that can increase or diminish in time, and adapts to the environment where she will be inserted. The wireless sensor networks can be applied such areas as medicine or security of the streets. The great advantage of this type of networks inhabits in the size that its elements can assume.

2. Available Technology’s

The problem described in the introduction allows the use of diverse technologies in its resolution. For the implementation of the solution it is used a wireless sensor network. However other technologies exist that could also be used.

A possible solution would be the use of GSM technology (cell phone) for the registration. Sending a SMS or with a phone call it could mark the beginning and the end of the parking. The paying was then deducted in the cell phone account.

Another form to register the vehicles was through the license plate. With a License Plate Recognition System (LPR) that get the license plate through the analysis of images, and use the licence plate to proceede with the registration of the parked car.

The localization could be gotten through a GPS device. However the GPS has a high cost.

There is a technology that allows the number of parking meters to be a few for city. It is a new wireless communication technology, WiMAX. The sender can reaches as far as 50 kms. The problem of this technology is its little penetration in the market and the few available devices.

After analyzed some technologies that could be applied in the system, we conclude that the best solution is the use of a wireless sensor network, for its advantages and for its low cost.

Wireless sensor networks (WSN) are composed by multiple devices with ability to communicate between them.

One of the characteristics, perhaps the most important, of the WSN is its necessity to be self-sufficient. This is a consequence of having a dynamic topology, the methods of distribution, the number of devices and the environment where they can be placed.

With the possibility to be added new devices to the network, the network needs to be scalable. A scalable network allows that if we need to increase the number of devices in the network, the network will continue working normally.

Next we will talk about the characteristics of the devices and how those affect the characteristics of the wireless sensor networks.

The size is the most distinct characteristic of the WSN devices these can reach up to 5 mm$^3$.

As an effect of the size, the devices have an increase of efficiency, that is, a reduction in the consumption of energy. The consumption is also affected by the use of low frequencies in the processor clock.

The processing in the devices has to have special attention to the available energy and to the life time of the devices. One of the characteristics equally affected by the size of the devices is the memory.

Multi functionality of the devices is one of the great advantages that these possess. The devices can be built in accordance to the necessities or proper characteristics of the environment where they will be inserted. The sensorial part of the device can also be modified in accordance with the necessities. Equally the type of communication also depends on what it is intended to be done with the WSN.

However the WSN do not only possess good characteristic, they also have limitations.

The devices of the wireless sensor networks have a great advantage, the size, however this advantage creates limitations. One of the limitations imposed by the size is its capacity of storage that limits the amount of information that these can remain.

Another existing limitation in device is related with the communication capacity. However another factor exists that also influences the communications, which is the available energy. Had to these two factors, size and energy, the devices tend to possess small antennas that compel to communicate with extremely short radio waves (high-frequency).

The bandwidth is limited by the available energy. To have an idea, the cost of sending a bit is equivalent to the cost of execution of 1000 instructions.
The limitation of energy also affects the processing capacity of the devices. Who in turn affects the complexity of the applications that can be created. That is a limitation because it increases the time spent in programming new applications.

In the area of observe ambient or habitats, the biologists use the WSN to observe vast areas that were impossible to watch using people, or observe places that should not be disturbed by human beings.

In accordance with some projects, the WSN are used to speed up the process of search for furtive shooters (9), the WSN detect the shot and calculate its origin, the available information is then sent to law enforcement.

Some possible applications are in the area of medicine where WSN are used to check the state of health of people at risk.

In the field of products the WSN can play some roles, from being labels, that when queried they disclose the characteristic of the product and its destiny, to prevent the product is sent to the wrong destination, or watchmen, during the moments where the products are stored.

The WSN can inclusively be applied to agriculture, giving name to a known area as precision agriculture. The WSN can be applied to military projects. There are projects that use wireless sensor networks to detect and to define the trajectory of enemy vehicles.

The localization started to appear as a necessity of some applications to know the localization of each element of the network. Currently there are a reasonable number of algorithms.

There are two types of algorithms, range-free and range-based. The range-free algorithms calculate the position in accordance with information sent from the senders. The localization in range-based algorithms can be calculated using diverse techniques. Some of the available techniques are: Time of Arrival; Time Difference of Time Arrival; Angle of Arrival and Received Signal Strength Indicator.

There are a great number of algorithms that can be applied to the WSN. Some of the existing algorithms in the area are the Centroid, the first algorithm created, the DV-HOP, adapted for balanced networks and the Amorphous, improvement of the previous one. These were the pioneer algorithms in the area. More recent is Mobile beacon, which uses a mobile device, the APIT that uses the test point-in-triangulation, ROPE uses distance bounding, the HiRLoc allows the use of three different techniques to reduce the error and the SMCL and MCB that had been created for mobile networks.

4. Description of the solution

In accordance with the chosen solution, were used three devices, one in the vehicle, one in parking meter and one in the fiscalizador.

The sensor in the parking meter have a link to a computer, this computer will be linked to a central office. The device in the vehicle is responsible for determining the state of the vehicle (parked or not parked) and communicating to the parking meter the parked car whenever it happens. The fiscalizador
communicates with the parking meter to obtain information of the parked cars. This fiscalizador is handled by a person who checks the parking places.

The objective is the creation of a wireless sensor network that manage the parking.

**SensorCarro**

Each vehicle possesses a device that we will refer as SensorCarro (SC).

The main function of the SC is to identify the vehicle in the network. However it possesses other necessary functions to the work of the system. One of the functions is to determine the state of the vehicle and calculate the localization of the vehicle.

When the state of the vehicle is *Parked*, the localization component proceeds to the localization of the vehicle. After determined the localization of the vehicle a message is sent to the parking meter to register the parking.

When the state of the vehicle is End Parking a message is sent to the parking meter to inform the end of the parking. After the parking meter determine the value to pay for the parking time it sends a message to SC to inform it about the value.

**Parking meter**

The parking meter will be equipped with device able to communicate with the SC. The parking meter is responsible for the necessary calculations in the parking process.

When receiving a message to register a SC, the PQ proceeds to the creation of a registration with the received identification. The records are kept in parking meter and send it to the central office.

When the parking meter receives the message that informs the end of the parking, the PQ proceeds to the calculation of the time expense and the value to pay. Determined the value, sends it to the SC and to the central office.

Parking meter still possess a component responsible for sending periodically position messages, these are used by the SensorCarro to determine the localization of the vehicle. The PQ still possess a specific component for the inspection, this component is responsible for sending the requested information to fiscalizador.

**Fiscalizador**

The Fiscalizador is composed by a device capable to communicate with the parking meter to query it for the information of the parked vehicles. With this information the inspector can verify if the cars are breaking the law.
5. Resolution of the problem

5.1. Problems

There had been several problems found in the implementation of the solution. It started with the problem of how to determine the state of the vehicle.

The solutions had several proposals, one of which was the adoption of an interface which used by the customer to signal the beginning and the end of the parking. But the intended system was an autonomous system that didn’t require any action from the client.

It is used a state machine that receives four different signals to determine the state of the vehicle. In accordance with the order which the signals arrive to the state machine, it determines the current state of the vehicle. When the state machine concludes that the state of the vehicle is *parked*, then the SensorCarro informs the parking meter of the parking. The parking meter is also informed when the vehicle abandons the parking.

This solution has the particularity of being completely automatically in finding the state of the vehicle. In such a way that the customer will always pay for the time parked. It also allows informs the customer in the end of the parking of the time spent and the cost.

The localization of the SensorCarro is an important part of the system.

Several algorithms had been searched for the localization. Most of them didn’t fit the system that was created. Two types of algorithms existed, to mobile localization where the localization is known at all instants and to static localization where localization is searched when its needed. For the system in mind the best suit localization was the static localization.

The chosen algorithm was the Trilateration. Using the force of the signal as form to determine the distance, this algorithm triangulates the position of the vehicle.

5.2. Algorithms

Description of the state machine

The state machine has to determine the state of the vehicle, if it’s parked or finished the parking.

So that can happen it was established that was necessary 8 signals so that the state machine could arrive at such states.

The signals have origin in 4 distinct areas of the vehicle, the engine (on or off), the divers door (open or closed), the drivers seat (free or on use) and the speed (stopped or on course).

For the system there only two states that interest, the *Parked* and *Not parked*. However to arrive at these states its necessary to pass thru other intermediate states, Stopped, Motor Off, Opened Door,
Free seat, to guarantee that we do not have false positives, that is, the state machine only signal one of the important states, parked or not parked, when these really happens.

**Description of the localization algorithm**

The localization algorithm of the management parking system determines the position using a technique that uses the geometry of triangles known as Trilateration. This is how the position is determine, however before being able to use this technique is necessary to collect information that allows its use.

To be able to use trilateration the algorithm is executed in two distinct steps.

In a first step we have the Parking meter periodically sending messages with its position. These messages are sent so that all the SensorCarro in the communication area.

In the second step of the algorithm we have the SensorCarro. After determining that the vehicle is parked, the SC goes to listening mode during a period time, during this time he receives position messages from the parking meter. From each received message is kept the position of the parking meter that comes in the message and the value of RSSI taken from receiver (radio). Finished the listening time, from all the collected messages are calculated the average value of RSSI for all the listened parking meters. The value of RSSI is then converted to distance with a predetermined scale.

With the values of distance and position from each parking meter then we use the trilateration to all the combinations of three parking meters. In the end with all the positions of the combinations calculated with the trilateration we calculate the geometric center of these positions.

**Description of the parking algorithm**

After finding that the vehicle is parked, through the state machine, the SensorCarro proceeds to the localization of the vehicle.

Determined the position the SC sends to the Parking meter a message with its identification and with its position, when receiving this message the PQ sends to the central office a message contending the data of the message and the initial time of the parking. The PQ answers to the SC with a message, contends information with the costs of the parking.

While the vehicle is in the parked state, there isn’t communication between the SC and the PQ.

When the state the vehicle gets to Not parked, then the SensorCarro sends a message to PQ informing that the car is leaving the parking. In this phase the Parking meter proceeds to calculate the spent time and the respective cost. After finished the calculations it sends to SC an account message, with the respective time spend and cost. The costs information sent to SC is the same information sent to central office.

When receiving the account message the SensorCarro show this information to the customer.
1.1. The Management Parking System

The SensorCarro is responsible for everything that is solely related to the car, determine its state and its position. In accordance with these necessities and to improve the software of the system, the SC was built with modules, allows changing one without damaging others.

Each module has its specific function.

The Communication module like the name indicates is responsible for all the messages sent by the SensorCarro. The State Machine module possesses a state machine to determine the state of the vehicle. This module receives signals from sensors, placed all over the car, in a defined order to be able to determine when the vehicle is or is not parked. The Localization module is used to determine the geographic position of the vehicle.

Finally we have the Base module. This is the main module of the SensorCarro, he determines the flow of execution of the received messages and for the received signals from other modules.

The Parking meter manages the parking records. It is responsible for everything that is associated with the parking. Has the responsibility to determine the parked time and the cost. The Parking meter also has to manage the requests from the fiscalizador (inspector device) and sent share information that allows SensorCarro determine its position.

The Parking meter is composed by a computer and a sensory part. The computer has a communication module. This module is responsible for sending to the central office the information of the parking records.

The sensory part of the PQ has a Fiscal module, responsible for answering the queries of the fiscalizador, the RegistoBD, keeps the parking records. This module is also responsible for the calculation of the parked time and the bill. The Communication module sends messages to their destination, the Localization module periodically sends messages with position information of the parking meter, and Base module is the responsible for determining the response given to the received messages.

The Fiscalizador (FC) can be considered secondary in the system, it solely as to inspect the parking places. It gets the parked vehicles list and its positions and verifies if vehicles are breaking the law.

The Fiscalizador is also composed by a computer part and sensory part.

The PC is needed to present the information to inspector who operates the FC and sow that he can insert commands. The communication between the FC and parking meter is carried through the Communication module.

If the inspector operating the fiscalizador doesn’t say which parking meter to contact the fiscalizador uses the localization module to determine which parking meter is closer and then send the query to that one.
In the Base module is determined the reply to give to the received messages. As already related this Fiscalizador is adapted to the available material, in a real system he couldn’t be like this.

6. Tests

After the system was built it becomes necessary to verify if it corresponds to the requirements.

We tested the state machine that is used in the SensorCarro to find if the cars is or is not parked. We simulated the signal sequence to find out if the state machine were giving the right answer. The results were the expected, the state machine only signal the state *Parked* and the *Not parked* when the signal were in the right order.

In a second test we tried to find out if the localization were working.

The test didn’t work as expect. The results of the localization where a little bit of a disappointing because the position determine by the algorithm was wrong to many times.

In the test we tried to find if the parking meter were responding to the fiscalizador, the results where the expected ones. The parking meter that replies to fiscalizador were only the one that was queried and the information replied was always correct.

7. Conclusions and Future Works

With this work it was obtained a functional prototype of the management parking system.

The prototype allows an autonomous management of the parking areas. There is no need for the customers to go to the parking meter to pay for the parked time.

It is used wireless communication between the devices of the prototype.

The system uses the real parked time, that is, it calculates the difference between entering time and exiting time of the parking. To the parking time it applies a tax. This part of the system is carried out by the parking meter.

The parking detention is carried out through the state machine in the SensorCarro. With the state machine it is possible to guarantee with great certainty that we do not have false positives. We can affirm that the system possess some intelligence in the parking detention.

With the prototype it is still possible to inspect the parked vehicles. A person operating the fiscalizador can obtain the records of parked vehicles or detailed information one record and check if there are parked vehicle that aren’t registered.

The prototype can locate the vehicles. This localization is used to have a better distribution of the records hover the parking meters. However there are some limitations in the localization.

With the improvement of the localization the system can offer other useful services to users.