# Intelligent Van Based on Wireless Technologies for Pharmaceutical Drugs Traceability and Incidences Reporting

A successful experience of using smart environments to resolve a real industrial need

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***Abstract*— This paper describes a telematic system based on an intelligent van which is able to trace pharmaceutical drugs over delivery routes from a warehouse to pharmacies, without altering the carriers daily tasks. The intelligent van understands its environment, including: its location, the assets and the predefined delivery route; and can report incidences to carriers in case of failure according to the established distribution plan. It is a non-intrusive solution which represents a successful experience of using smart environments and a RFID in a viable way to resolve a real industrial need.**

***Keywords-intelligent van, pharmaceutical drugs traceability, incidences reporting, non-intrusive, RFID, wireless technologies.***

## I. INTRODUCTION

Pharmaceutical drug supply chain, from an economic and health perspective, requires controlling all stages of distribution: from drugs are produced in a laboratory until they reach the pharmacies. This requirement is reflected by the Ministry of Health and Consumption of Spain through the new Royal Decree of drugs traceability, redacted in accordance to Directive 2003/94/EC of the Commission of the European Communities [1].

Adapting to the changes required by regulation imposes severe changes in the business model of different actors involved in the pharmaceutical sector. Moreover associated costs are hardly feasible in a highly competitive industry where profit margins often are set by administration.

The features of the existing application scenario in drug delivery from the warehouse to the pharmacy carry particular difficulties. The huge competition between pharmaceutical distributors forces them to preserve a high quality service in terms of delivery time and reliability. Inside a market where all competitors are offering the same products at similar prices, service quality is a decisive factor because an incomplete or incorrect shipment can result in the loss of a client. These requirements fall on the carrier which is required to complete the route in minimum time without making any mistakes during delivery. For these reasons the need to deploy a system that meets the new regulations should be carried out through a system that does not complicate current tasks of carriers. The installation of a system that requires the carrier to use hardware devices such as handheld RFID readers or Datamatrix adds new tasks in a job already stressful enough. Generally, each route is conducted at least four times a day and a significant delay or wrong delivery often results in the loss of a pharmacy that changes of dealer. Therefore, the job of the carriers should be thoroughly reviewed to avoid mistakes and if they commit to define responsibilities. This scenario causes significant disagreements between staff transport and store.

This paper presents a system designed to adapt the distribution of drugs to the new regulatory environment that does not alter the behavior of workers involved in it. The onboard module in each delivery truck will collect all the information required for traceability without any interaction. Furthermore, this system is responsible for validating all actions which vary the cargo during development of a route by interfering with the activity of the carrier only if it detects a deviance with respect to planning.

This paper is divided into three main parts. Initially indicate the functional characteristics of the system presented, then be described in depth the container identification system inside a van and later detail the architecture of the modules necessary to provide intelligence to vehicles used. Finally through the conclusions will show the results of implementing the system in a real warehouse for distribution of pharmaceuticals in the north of Spain.

## II. INTELLIGENT VAN

The intelligent container concept is not new in logistics and distribution processes. However the specific needs of the scenario corresponding to the distribution chain of medicines requires the development of a customized solution. Furthermore the high cost of RFID tags impedes implementation of such systems in real applications specially in scenarios with heterogeneus load [2]. The use of tags 13.56 MHz HF frequency range with limited reading distance, limit the identification of the packets to the moment they are loaded or unloaded. The proposed system uses long-distance UHF tags to know the vehicle cargo at any time.

Two of the main characteristics of this project are to control medical distribution all over the delivery route and to make carriers work easier among others. An intelligent system has been established introducing Radio Frequency Identification technology (RFID) in drugs distribution. This technology is optimal to know the traceability of all drugs delivered and facilitates the drivers to load and unload the cargo because if something goes wrong, the system will alert indicating the failure.

Focusing on the general process, in the beginning, automated medical dispense robots have to coordinate orders for each pharmacy. This system organizes all requested medicines in containers, and then all of them are sent to the dock ready for loading vans. There is a passive transponder attached to each container so its EPC code can be related to what drugs are on each container and the pharmacy destination for each one. Spanish law will allow the use of two technologies, Low Frequency RFID and DataMatrix for the identification of individual packages of medicines. A second phase of this project that will begin in the fourth quarter of 2011, will implement a robot that can dump the contents of a container and validate, based on identification technologies approved, the packaging of medicines contained within. Thus the system will meet the requirements of traceability required by law.

Fig. 1 shows the process flow indicating the communication established between the three main parts of the system: embedded platform (EMB PLA), mobile device (MOB DEV) and central server (CTR SRV). When the delivery van arrives at the warehouse, the embedded device installed on each truck is connected to the network of the warehouse via WiFi and is allowed to download from the corporative Enterprise Resource Manager (ERP), all the necessary information about the next route the vehicle must perform. This info includes the number of containers that must be loaded into the wagon and the Electronic Product Code (EPC) of each transponder attached to containers that have to be distributed along the route.

At this point, carriers start to load vans with their corresponding containers. An RFID reader module is located inside the van and each container has attached a passive tag so that it can detect each container that enters or leaves the wagon. It is very important to emphasize that this is a non-intrusive system. The carrier does not have to be worried about registering loaded or unloaded containers because the RFID of the proposed system does it automatically. RFID module detects transponders EPCs and transmits them to the embedded platform connected. This device stores all the information needed for a correct delivery and monitors what the carrier is doing at anytime.

If the carrier makes a mistake loading or unloading a wrong container a red light will switch on in the wagon and he will know that there is something wrong. Since all van drivers carry a Smartphone with them, an application for it has been designed, so the Smartphone is considered an element of the proposed system. That mobile is connected by Bluetooth to the van's embedded platform, so it knows the list of containers to load into their vans and which containers are being loaded or unloaded. Therefore when the red light switches on, the carrier will get an error message generated by the proposed system in his Smartphone. He will try to solve it by himself and if he cannot do it, the Smartphone will send an incidence to the warehouse manager and that incidence will be registered in the embedded device too. The mobile application runs resident on the smartphone and is only accessed by the carrier when the red light indicates an error, so the app shows the description of undertaken mistake. In the event that the development of the transport process is executed as planned the carrier does not need to open the application and adds no new tasks to usual job.

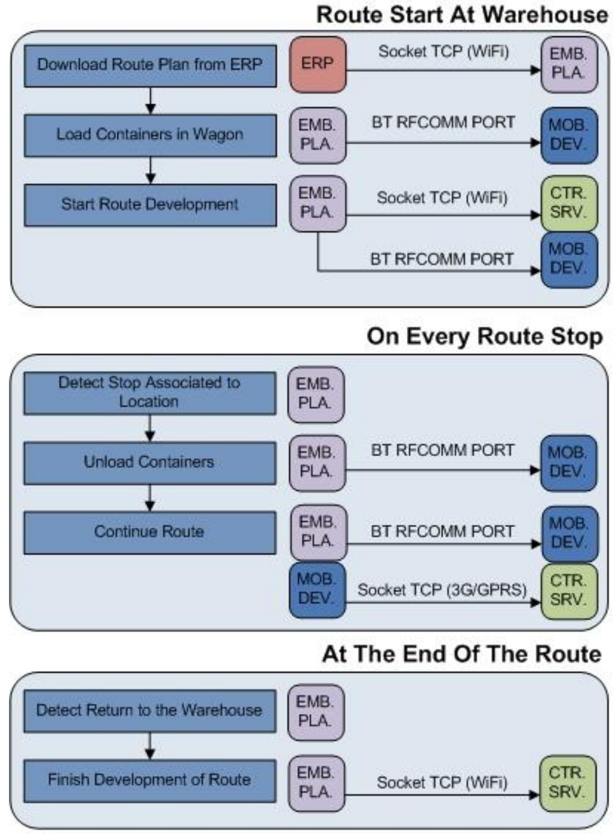


Figure 1. Process flow diagram of the system.

Once the van is loaded, the van driver starts the delivery. He has a route of pharmacies where he must unload some containers at each time. With the Global Position System (GPS) transceiver incorporated within the embedded device, the van knows its rough location every time. So the intelligence of the system calculates which containers to unload in the next pharmacy and in the other ones. When the van stops and the wagon door is opened the system detects the nearest pharmacy included in the route accessing which containers should be unload at this point. When the carrier unloads all containers associated with that stop and no more, the system activates the green light, indicating that unload is correct. If after downloading all containers, the red light remains on, the carrier must enter the mobile application to detect the cause of the error. If there is any divergence that cannot be solved, the carrier can continue to the next stop and the system immediately reports an incidence to the warehouse manager.

As it is a non-intrusive system, the carrier must do his job as usually. He will not realize that behind him, there is a system controlling every movement that he makes, and only he will be notified in case of an error.

The system in addition includes atmospheric sensors inside the wagon for temperature, pressure and humidity control transported goods.

The embedded platform saves in a Secure Digital (SD) card, at regular configurable intervals, the location of the van, EPCs of containers loaded and the values of the atmospheric sensors. When the route ends and the van returns to the pharma warehouse, the device connects to the network of the warehouse via WIFI and sends an XML file through File Transfer Protocol (FTP) containing all the information stored during the development of the route. This allows the warehouse manager may subsequently review the development of a route through the control panel and look for causes of undertaken errors and delays.

## III. Cargo Identification System

According to the OMS drugs must be stored and transported under certain conditions. One of them is the need to use standardized and reusable containers to transport those drugs from warehouses to each pharmacy office.

This fact constitutes a perfect scenario for RFID technology and this project in particular. It can be controlled what drugs go to each pharmacy if they are inside a registered recipient. And working with a GPS, the system knows the place where containers have left the van. Attaching one passive tag to each container, not only it can be monitored when the containers enter or leaves the van, but it also makes the investment in tags to be easily affordable in a very short time, avoiding one of the biggest drawbacks of this technology. Carrying drugs into containers that have attached a transponder also allows its tracking and the traceability of each medicine.

The intelligent system designed is based on several technologies, but one of the most important is RFID. This technology uses two basic elements, a reader or interrogator and a tag or transponder. As already mentioned, passive transponders have been attached to containers exploiting its reusability, and an RFID reader has been placed inside each van. To enhance the reader's gain, several tests have been made with different antennas and with different antenna locations. Some of them will be described.


Figure 2. Confidex's Carrier Tough passive tag.

### A. RFID tag

A Confidex's Carrier Tough (Fig. 2) tag has been chosen to be attached to a container. It is a passive tag (do not have any batteries) covered in hard plastic and resistant to mechanical stress, friction and shock. It also has a paper with a 2-D Data Matrix that is useful for other applications in other parts of this supply management.

It works using EPC Class1 Gen2 protocol, its frequency range is from 860 – 960 MHz and its reading range is from 4 to 6 m, enough for a wagon van.

The price of tags is decreasing year by year, but it still remains a problem for many companies to adopt this technology. The reusability of these transponders thanks to the fact that they are stuck on the wall of the containers and not on each drug box, makes RFID an adequate technology for the project because of its easy investment recovery.

### B. RFID reader

An RFID reader is located into each delivery van. This is in constant communication with the embedded device next to it and tells the reader to read tags and send received EPCs of the transponders inside the wagon when the system needs it. This reader module has on one side, RS-232 communication with the embedded device, and on the other side, wireless communication with the passive transponders attached to containers.

It has been used a Thing Magic's Mercury5e-EU RFID Reader [3]. This works at the UHF range of frequency to improve interrogation distance and bears EPC Gen2 protocol, more robust against noise and reading interferences. It has 30 dBm of read gain at the range of 865.6-867.6 MHz according to the European Union regulatory support ETSI (EU) EN 302208. With an antenna of at least 6dBi, it can read tags in 9 m because of its sensitivity of -65 dBm.

The working procedure of this system starts with the embedded device. It asks for the information of tags inside the van sending a request through serial port. The RFID reader starts generating a continuous wave to power up the

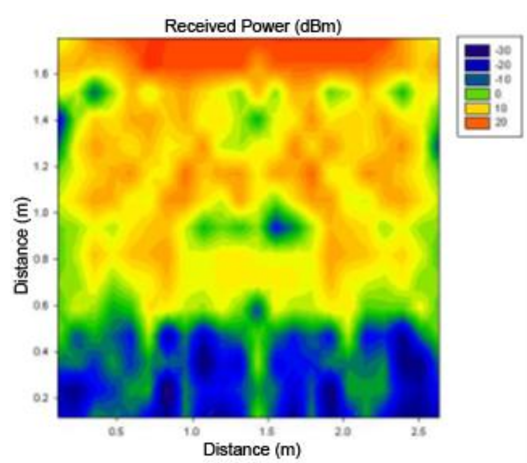


Figure 3. Estimation of received power [dBm] on the second floor of containers, obtained by full 3D ray launching algorithm.

tags stored into the van and these tags answer their EPC codes (96 bits) modulating the continuous wave generated by the reader [4]. To detect all those backscatter signals generated by transponders [5], a high gain antenna is connected to the reader and is strategically located into the van. In this manner the reader improves its reading range against low power answering of transponders and enlarges covering inside wagon. Once it has completed a read cycle, the reader sends back through serial port all EPCs stored in its internal buffer to the device.

For tests, some useful parameters have been used to improve detection of the tags. When the reader communicates with a tag it stores the received signal strength indicator (RSSI) of the tag read. And it also stores the time the tag was read, relative to the time the command to read was issued (Timestamp). Those parameters have helped to take a decision on where to locate the antenna to get the best tag detection results.

### C. *RFID antenna*

To enhance coverage over the wagon an antenna for the reader is needed. As it has been said, with a 6 dBi antenna, the wagon of a standard van can be covered. Some tests and simulations have been made with different commercial antennas of at least 7 dBi of gain and a self-designed one.

These simulations have been made using the van as scenario to see commercial antennas behavior. The wagon has been modeled as a metallic cube full of polypropylene containers and the antenna has been placed at different locations in the ceiling of the van. Simulations are based on the deterministic method of a 3D beam source [6] to analyze the inside of a van full of containers. A linearly polarized PATCH-0026 and a circularly polarized PATCH-0025 have been used. Both ones have very similar parameters except their polarizations.

Both antennas have a similar reading range behavior because the van is a closed metallic environment so there is multipath propagation. The RFID reader will receive a direct component, if there is direct visibility, or there will be a great number of echoes with different amplitudes, phases and random arriving times. The circularly polarized antenna has been chosen because it has the best coverage over the wagon. Figs. 3 and 4 show the power distribution inside the van using the latter antenna. They respectively depict an estimated power received by likely tagged containers that are located at the second row of the packing distribution and that in an isotropic view. It has been placed at the back of the van in the middle of the ceiling offering the best results of the simulations done. Because of its polarization, tags can be read in any orientation. In an environment like this one, the transmission power decreases with distance with a lot of variations, due to the number of multipath components.

### D. *Antenna design*

To meet the demands of the proposed system in section III, utilising RFID, a customized antenna interrogator design is preferred over the commercial required. Typically, high gain antennas imply larger sizes Current simulated results indicate that antennas having gains of 2dBi are adequate for in-vehicle applications. They can deliver a sufficient radio propagation field inside a vehicle; this assumes full power transmission at the transceiver [3]. The antenna interrogator is being set in the middle of the ceiling of the car as a preferred location in vehicles [7]. This ensures good power distribution to likely RFID tag locations within the car while minimizing field exposure to potential occupants (those assisting in the inventory distribution of goods). Antennas inside a metal shielding can theoretically confine the antenna's radiated power within the car body with no power loss, no Doppler shift on moving vehicles. Directly printing (i.e: electrically conductive paint) antennas onto suitable surfaces are encouraged as a great opportunity to provide relaxed and relatively inexpensive mass-produced antennas. Recent advances in electrically conductive paints [8] can provide adequate sheet resistance for the development of cost-efficient antennas.

The geometry of the sprayed antenna design is presented in Fig. 5. It depicts a relatively simple structure that encompasses an easy fabrication and is suited for use in radio frequency identification networks using the unlicensed RFID subband b2 (8.656-8.676 GHz) of the ETSI standard [9].

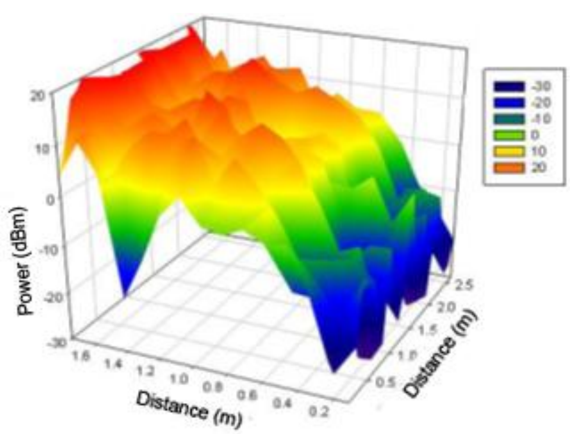


Figure 4. Volumetric view of simulated values of received power [dBm] on the second floor of containers seen from the side.

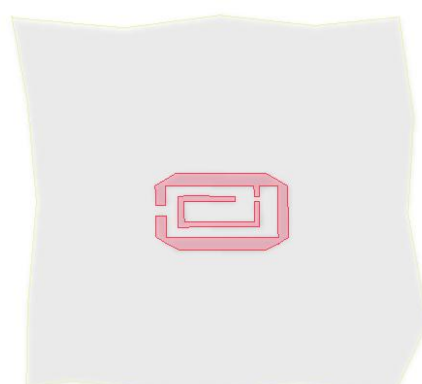

Figure 5. The antenna printed onto a car body

Simulated results expect an antenna having a sufficient bandwidth for the application and a 2dBi gain when using copper ink. Recent studies show a similar performance using silver and a lower efficiency antenna using other conductive paints such as nickel [10]; copper is therefore the preferred ink used for the antenna application. Radiation patterns show a directional antenna characteristic that can be useful for in-vehicle applications [11]; as a result, the antenna enhances the system coverage inside a vehicle.

## IV. System Architecture

System architecture is structured on the basis of the embedded device installed in the van. Because of the capacities of this device and its wireless communication with other resources (both individuals and hardware resources) we can base on it our proposed intelligence system.

This system can be decomposed into three distinct parts: the embedded device itself, responsible for bringing together the information obtained by the hardware components of the van; the mobile application and the control software solution. In this section we are going to describe each module of the system from a functional and technical point of view.

### A. Embedded device

The Embedded Device is the main communications system and thus, the core of the intelligent cargo solution. It detects containers using RFid technology, and communicates with the central server and the mobile unit with its embedded Bluetooth and WIFI modules.

Due to the incorporated data about the routes to follow, the sensors embedded, and its integrated geopositioning capacities, the device also provides to the van driver the knowledge necessary to optimize routes and therefore, the quality of the service.

Warehouse automated dispensing robots made the coordination of the orders of each pharmacy. In the moment a new order arrives, the system stores all the medicines required within a container that will be sent to the dock ready for loading vans. When the truck arrives at the warehouse a WiFi connection is initiated between the embedded device, installed in each vehicle, and the server. The device download all the necessary information and updates the EPC of the containers to be distributed along the path. It also updates the location, the number of stops and what are the containers to unload at each stop. With its RFid module, it can detect tags attached to each container loaded into the van, so that it can warn the dealer with a red or green light if there are errors or not in the process of loading and unloading the cargo.

This procedure ensures, in a non-intrusive way, the proper conduct of the routes assigned to the van driver. This is done using the intelligence provided by the various hardware components involved (antennas, sensors, tags, etc.) intercommunicated via wireless technologies (WIFI, Bluetooth, RFID) and its associated information system. All these elements conform the system architecture of the proposed ubiquitous computing solution.

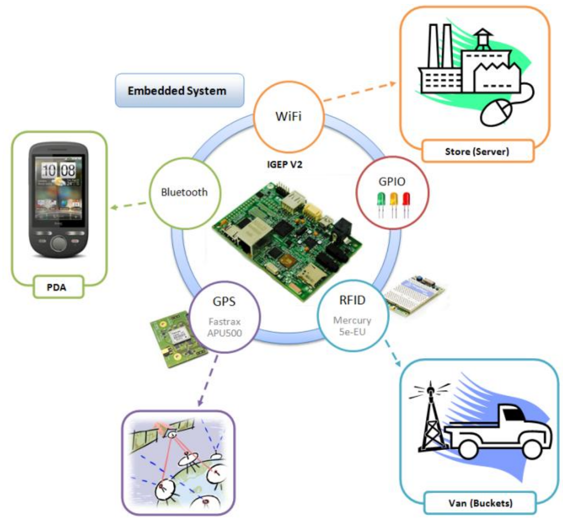


Figure 6. Embedded device conectivity

The main device used to implement all these features is an ISEE IGEPv2 based on an 1GHz ARM Cortex-A8 processor stand-alone computer-on-module. This is a small size card (93x65x15mm.) that has all the communications modules and resources demanded by the project. Embedded platform runs under a Linaro distribution with a Linux kernel optimized for this specific board. It includes WIFI IEEE802.11b/g communication capability used for updating information at the warehouse and a Class 2 Bluetooth 2.0 module with a range of 10 meters, able to communicate with the mobile application of the driver. Platform provides several Global Purpose Input/Ouput pins (GPIO) that are used to activate red and green lights and to detect when the wagon door is opened. Furthermore, this board has two serial ports (UART) which are used for communication with the RFID reader and an external GPS receiver (Fastrax i310). Finally, the embedded platform has an SD card that stores the historical data acquired during the development of the route that are subsequently transferred to the central server.

The RFid reading system is composed of a Mercury5e-EU RFid Reader, two commercial high gain antennas and passive UHF tags attached to each container. The reader works at the UHF frequency range to improve interrogation distance and bears EPC Gen2 protocol, more robust against noise and reading interferences. To detect all signals generated by transponders, two high gain antennas are connected to the reader and are strategically located into the van. In this manner the reader improves its reading range against low power answering of transponders and enlarges covering inside wagon.

### B. Mobile application

Installed on a Smartphone. Van driver uses it to interact to the embedded system using a user-friendly graphic interface. The integration of a mobile device in the environment of the proposed solution can complement and supplement the system, serving the driver as an entry point to

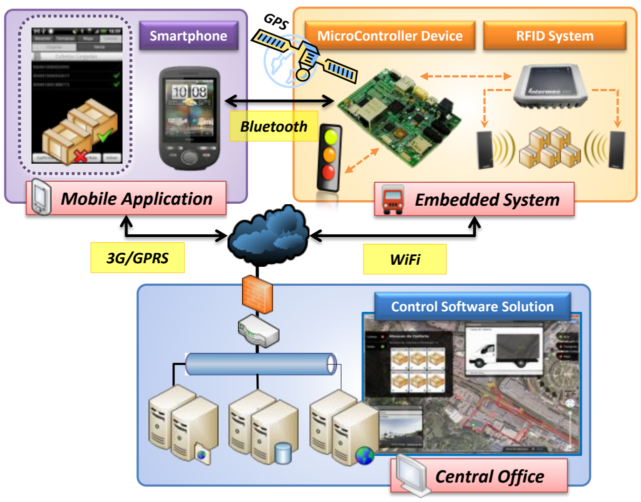


Figure 7. System architecture and interactions

the knowledge offered by the embedded system in a more comprehensive manner, always maintaining the desired level of non-intrusiveness.

Android technology has been used for the development of the mobile application. This decision is motivated by the opportunity offered by the pharmaceutical transport company CENFARTE (Centro Farmaceútico del Norte S.A) with which it has been established an active collaboration to enable the implementation of a real pilot of the solution. The company has the means to have an Android terminal for each route or carrier. As a result of that, each driver carries a Smartphone to stay connected to the server application in order to know all his needs on every transport service.

The wide range of terminals and the variety of operative systems has forced us to develop a multiplatform application that works on the majority of newest existing smartphones, including Android OS, Apple iOS and BlackBerry OS.

To achieve this goal, the development has been focused towards a SOA (Service Oriented Architecture), in which most of the functionality is distributed in the server, freeing the processing load to other devices that will access the logic through SOAP messages to a web service developed for the control software solution.

Once transportation is available to perform a service, the application displays the routes that are currently available. It does so through a WIFI connection to the server, accessing the web service responsible for obtaining the daily routes not yet started. In case of failure of the WiFi connection, the system offers continued support in communications through GPRS/HSPA connectivity present in the mobile device.

Once the route is established, the mobile device obtains data about the full path: distance, estimated duration, number of stops, addresses, etc. Similarly, for each of the established stops relating to the pharmacies on a route, are obtained concrete EPC codes of containers to download. This information is accessible via another web service that fulfills the function of data-oriented middleware enabling the capture of real-time information from the ERP system implemented in the company. The developed system obtains the information in a transparent and non-intrusive manner, not being necessary expensive modifications in the legacy order management system. All this information is displayed to the carrier through an user interface designed with the intent to facilitate maximum usability and minimize intrusiveness.

The application core functionality is the management of incidences, giving as an added value support for transport activities and navigation aid:

*1) Management of incidences:* As discussed in previous sections of this document, the proposed system intended to give the van driver an aid in its daily operations. One of the activities that is more prone to error is the loading and unloading of the containers, and hence the developed system alerts the driver via a led indicator of its correct execution.

However, other incidents that may occur must be taken into account, such as deviations in the estimated route time or the loss of containers in the pharmaceutical stores. It has been established that more than 10% of deviation in the estimated time for the delivery of an order or a non-conformity in the containers to download must generate an automatic incidence. When the system detects a lost container, the embedded device sends by Bluetooth to the mobile application how many containers are missing in order to request for them to the store administration.

All this incidences are managed by the mobile application, simultaneously alerting both the carrier and control center. This will be achieved using communications established via GPRS/HSPA between the mobile device and control software solution.

The van driver will have the opportunity to see on the smartphone at any moment which is the state of the route, which issues have been generated what are the activities to be undertaken to resolve them. As seen, the mobile application helps the carrier in the development of daily activities, allowing to reduce operational errors in the process significantly.

Navigation aid: once in the course of the route and since these are changing according to the pharmacies involved in them, the mobile device offers integrated navigation service for helping the carrier. It shows the route, indicating the order in which the driver must make every stop on the planned route and if it is necessary, it assists delivery man in navigating from one point to another in that route.

*2) Support for transport activities:* at each stop, embedded device reads RFID tags and detects changes in the cargo that are sent via Bluetooth to the mobile application. This data relating to the operation of the carrier in the loading or unloading of containers, provides real-time information about possible deviations (human errors in cargo management) allowing warehouse staff to rectify the errors on delivery in minor time.

### C. Control software solution

It has been developed an application for monitoring medicines traceability, to schedule optimized routes and to locate different vehicles of the vans fleet.

This software solution includes the development of a control panel that includes three main functional features:

- Medicines traceability: the system has a robust database where all delivery information is stored. That is, pharmacy office in which each medicine unit has been distributed, indicating batch number and expiry date. It allows user to search for a container even if it has been downloaded in a pharmacy office or if it is inside a van during a transport service.
- Fleet management: the system can locate different distribution vehicles on a map, it can store completed routes and the time spent on each stop. It contributes to the distribution company calculating an approximated time left to deliver a batch on a pharmacy office. It also calculates optimized routes taking into account delivery time, traffic and preemptive supply.
- Optimized schedule fleet: taking into account database stored information, using artificial intelligence techniques and generating information by ERP, the application generate routes for each vehicle optimizing time of delivery.

All this functionalities have been developed on a Rich Internet Application (RIA). Below are listed the technical characteristics of each of the parts that compounds the traceability control service: the data model, the web services and the web application.

*1) Data Model:* data that should be stored by the application has been conceptually modeled. Microsoft SQL Server 2008 DBMS has been used in this context. The process of storing the operational data of transportation occurs at the end of the route. When this occurs, the onboard device is connected via WIFI to the server and sends a generated XML file which includes both the actual path followed by the vehicle and the incidences that may have occurred. This file is automatically treated by the system, generating the necessary entries in the DBMS so that the route is recorded at the time of its completion.

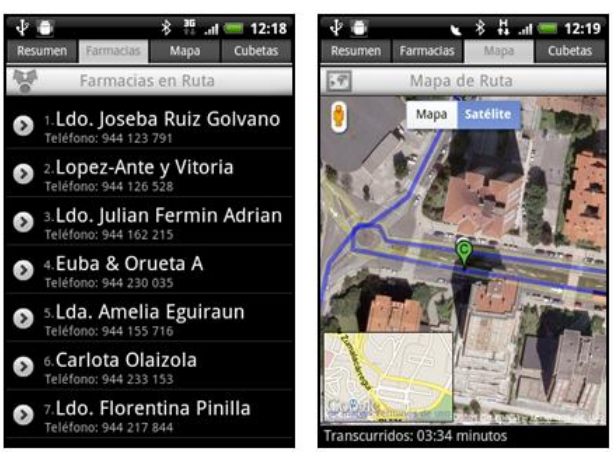


Figure 8. Mobile application interface.

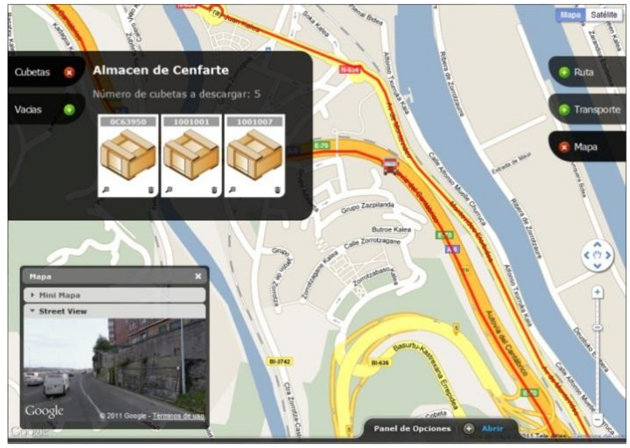


Figure 9. Web application interface.

*2) Web Services:* information relevant to the application is in the DB; however, access to such information is done through Web services developed with WCF technology (Windows Communication Foundation). This technical decision allows both data and application logic can be accessed from other devices, thereby ensuring the scalability and interoperability of the whole. Security also is increased because the data access does not occur directly but through the services, providing greater control over database queries. The network will be controlled at all times under a firewall that prevents unauthorized access. The set of services developed allows full interoperability between the different components of the system, which is a major benefit in broadening the number of devices compatible with it and facilitate their development in the future.

*3) Web Application:* the development of the control solution is completed with the web application which offers features beyond the typical application of fleet management. This application has been developed taken into account two fundamental characteristics: (1) to maintain a friendly and attractive interface, (2) without prior installation or further configuration. This Web application approaches usability to a modern desktop application but with all the advantages that such implementation offers, being available globally via the Internet to a vast number of devices supported.

The Control Panel, based on asp.NET development framework, has been made extensive use of technologies designed for creating Rich Internet Applications (RIA): JavaScript, CSS3, HTML5, Ajax and jQuery, along with the use of the tools offered by Google for displaying and processing of geographic and positioning information. This feature improves not only the final visual aspect of the application but also the overall usability. The whole site is based on an asynchronous behavior, so interaction eliminates the sense of loading data and responds instantly. All kind of choices as routes, stops or containers represent a dynamic and transparent loading of data and an almost immediately response to their interaction.

## V. Conclusion and Future Work

Profits that item-level traceability for pharmaceutical drugs provides to society in terms of public health and ensuring access to medicines enforces governments to require this feature to the different actors involved in the pharmaceutical supply chain in the short term. The reduction of profit in the pharmaceutical industry motivated by the imposition of certain public policies hardened because of the economic crisis affects not only to laboratories but also to distributors of pharmaceutical products that are unable to afford the investment needed for these systems. Most of the initiatives to apply telematic technologies in order to fulfill requirements imposed by governments are being designed without considering the difficulties of deploying such systems in the storehouses currently working on and in their impact in the activities of the pharmaceutical supply chain.

In this paper we have presented a system based on an intelligent van to improve the distribution of pharmaceutical drugs. The system is able to trace medicines over the delivery routes from warehouses to pharmacies, reporting incidences to carriers in case of anomalities in the distribution plan. This contributes, first to the reduction of the occurrence of errors during distribution and the required time for their recovering, and second to locate a set of medicines in case of a mislead.

In order to achieve these tasks, the intelligent van has to identify its environment, including: its location, assets which are insides, and the current delivery route. To meet the demands above, current wireless technologies were used, it includes: RFID to provide with the cargo identification; GPRS/HSPA, WIFI and Bluetooth to achieve communication; and GPS for the geo-positioning provision. Moreover, interaction with the user has been provided through the integration of a Smartphone in the system.

The main technological contribution of this work is the use of telematic technologies for providing intelligence to a van; this is to improve the distribution of pharmaceutical drugs without altering the way carriers do their tasks. Carriers using the intelligent van will relax from worries about registering (loaded or unloaded) pharmaceutical drug containers; they require no continuous supervision because the system validates every task they make, notifying them only in case of a deviation according to the planned route. It is a non-intrusive solution representing a successful case in using smart environments to resolve a real industrial need.

This has been possible due to first, the design of the technological solution and second, the characteristics of the scenario in which the systems is deployed. The "Good Distribution Practices for Pharmaceutical Products" drafted by the World Health Organization states that all pharmaceutical products should be stored and distributed in containers with no adverse effects on the quality of products, and offering adequate protection from external effects. Thanks to the standardization and reuse of these containers, the transportation of drugs is an ideal scenario for the implementation of RFID tags. The actual high cost of UHF tags is well amortized by a provided application capable of geo-positioning the precise location of lost containers. It makes the costs of purchased tags affordable in a very short time investment, avoiding one of the biggest drawbacks (the cost) of this technology.

Finally, among the future prospects to improve the proposed intelligent system, we can highlight the following. First, after several tests using different commercial antennas and locations inside the van, the next challenge is to design a customized antenna. Ongoing development of a miniature antenna that is aimed to be printed onto the car body seems to be an efficient technique to simplify the fabrication and reduce costs; this is exciting to the automobile industry. Second, in order to improve the reliability of the system we are designing a validation device able to dump the content of a container (loaded of medicines) and pick-up its content through the identification of a 2D bar code. The device should be integrated into an automated robotic dispensing system of pharmaceutical products for warehouses and aimed to guarantee the right content of containers that are to be packed in the van.

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## REFERENCES

[1] "Commission Directive 2003/94/EC of 8 October 2003 laying down the principles and guidelines of good manufacturing practice in respect of medicinal products for human use and investigational medicinal products for human use," in Official Journal of the European Union. ISSN 1725-255. L 262, Vol. 46, 14 October 2003.

[2] R. Jedermann, W. Lang, "The benefits of embedded intelligence: tasks and applications for ubiquitous computing in logistics", IOT'08 Proceedings of the 1st international conference on The internet of things, Springer-Verlag Berlin, Heidelberg ©2008, ISBN:3-540-78730-5 978-3-540-78730-3.

[3] ThingMagic, A Division of Trimble [online] available at http://www.thingmagic.com/embedded-rfid-readers/mercury5e/1-embedded-rfid-readers/3-mercury5e.

[4] Klaus Finkenzeller, "RFID Handbook, Fundamentals and Applications in Contactless Smart Cards and Identification", 2nd ed., Jhon Wiley & Sons Ltd., 2003.

[5] Mervi Hirvonen, Kaarle Jaakkola, Pekka Pursula, and Jussi Säily, "Dual-Band Platform Tolerant Antennas for Radio-Frequency Identification", IEEE Transactions on Antennas and propagation, Vol. 54, No. 9, pp. 2632-2637, Sept. 2006.

[6] Saez de Adana, F. and Blanco, G. and Diego, G. and Arriaga, P.and C´atedra, M.F., "Propagation Model Based on Ray Tracing for theDesign of Personal Communication Systems in Indoor Environments"Vehicular Technology, IEEE Transactions on, vol. 49, no. 6, pp. 2105–2112, November. 2000.

[7] I.J. García Zuazola, J.M.H. Elmirghani, and J.C. Batchelor, "High-speed ultra-wide band in-car wireless channel measurements"; Communications, IET, Vol. 3, Issue 7, July 2009, pp. 1115 – 1123

[8] Applied Nanotech Holdings, Inc [online] available at http://www.appliednanotech.net/tech/inkjettable_metallic_inks.php

[9] Technical Report Electromagnetic compatibility and Radio spectrum Matters (ERM); Part 2 ETSI TR 102 644-2 V1.1.1 (2009-03)

[10] A. Koptioug, P. Jonsson, T. Olsson, J. Sidén, M. Gulliksson, "On the behaviour of printed RFID tag antennas, using conductive paint", Proceedings of Antenn-03, Kalmar, Sweden, 2003.

[11] Hovinen, V., Hamalainen, M., Patsi,T., "Ultra wideband indoor radio channel models: preliminary results", IEEE Conference on Ultra Wideband Systems and Technologies, 21-23 May 2002, Wyndham Baltimore Inner Harbor. Baltimore, Maryland USA, Page(s):75-79.