MONITORING AND TRACING SYSTEMS IN A REAL OPERATIVE ENVIRONMENT OF A PORT CONTAINER TERMINAL

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ABSTRACT: The Mediterranean (MED) Sea has always been and continues to be a vital space for the circulation of goods, with its significance extending beyond the interests of bordering countries. MED ports and the maritime commerce they handle have provided a boost to both regional and European economic development. Nevertheless, the circulation of goods/capitals within the MED Sea faces a number of challenges.
ICT technologies, such as Differential GPS (DGPS) and RFID have proven of to be of great value in tackling MED/ EU port challenges regarding logistics and communication systems.
It is a rapidly growing technology that has the potential to revolutionise port terminal processes as well as inventory control and logistics. Nevertheless, it is not yet extensively deployed, mainly due to system incompatibilities in the transportation and storage chain, the physical state of the terminal as well as non-negligible deployment costs.
Within this framework, the INTE-TRANSIT project (Integrated and Interoperable Maritime Transit Management System) aims to use modern/emerging ICT technologies (e.g. DGPS, RFID, OCR) to improve logistics activities via enhanced container localisation and queuing.
The main objective of this paper is to describe the achievements of the Valencia pilot implementation; to highlight the technology used, the solution proposed, the identified challenges (RFID identification, GPS position, communication, high quality hardware, and so on); and to present some conclusions.

Keywords: Container tracking, Monitoring&Localisation System, Valenciaport, RFID, DGPS.

INTRODUCTION

The INTE-TRANSIT project is a European project forming part of the MED Strategic Programme (STC MED). The MED Programme is funded by the European Union as a regional policy instrument and works towards "European territorial cooperation".

The Mediterranean area is made up of countries that are open to the rest of the world, but at the same time are at the periphery of Europe. Southern Europe is characterised by its geographic dispersion resulting in lower growth and more restricted transport capacities when compared to the metropolitan areas of Northern Europe.

The programme aims to strengthen cooperation between Mediterranean countries in order to achieve economic and social cohesion and, therefore, sustainable development for the entire European Union.

The INTE-TRANSIT project [1] focuses on strengthening communication links between i) ports and relevant authorities across the MED Basin, ii) all relevant actors in maritime transfers and iii) ports and their logistics activities areas, by employing modern Information Communication Technologies (ICT) that will be used to enhance information management systems. Within this framework, five pilot projects are implemented in order to demonstrate the improvement in logistics systems and port operations.

The current paper refers to the ICT technologies based on DGPS and RFID, which were deployed in the Valencia port pilot.

Specifically, the INTE-TRANSIT Management System (ITMS), developed in this context, uses RFID tagging technology to identify containers and Differential GPS (DGPS) technology to provide precise location information for containers as well as for the monitoring of the yard equipment. These technologies are supported by a modular management server, which is responsible for collecting, storing and representing gathered data (real-time or on-demand) to the relevant end-users, in this case the port operations personnel. Automated processes and mechanisms for writing, reading tags, logging, alarms and data reporting enhance the real-time operational visibility and control of the containers and yard equipment as well as their management and utilization.

The proposed pilot incorporates different types of the abovementioned technologies to address the monitoring of containers during the normal yard operations of a port container terminal.

VALENCIA TERMINAL PILOT DESIGN & REQUIREMENTS

The Valencia terminal pilot aims at developing a way to track and trace containers and equipment in the yard area of a terminal.

From the terminal process point of view, the objectives are:

- The automation and improvement of port operation productivity and container/cargo traceability.
- The enhancement of the existing container terminal management and control systems These objectives have been achieved by introducing modern positioning technologies in

order to monitor yard and transfer equipment as well as the containers they handle. This has automated the location of containers and equipment within the terminal and has provided real-time information about the status of the stacks and the equipment that can be used for route optimization.

VALENCIA PILOT SCOPE

In order to accomplish the abovementioned objectives, the Valencia Pilot deploys the ITMS composed of two main subsystems: the Intra-Terminal Truck Positioning System (TPS) and the Container Positioning System (CPS). This software platform collects aggregates and manages positioning and ID data.

The data is principally obtained using DGPS and RFID technology, which also need to be installed for the pilot.

Therefore, the scope of the Valencia Pilot consists of applying the ITMS, but also includes the implementation of: hardware components installed on port equipment; IT hardware infrastructure; software based tools and applications; network infrastructure; and tagging elements installed on containers.

VALENCIA PILOT – CONCEPTUAL DESIGN

The Valencia Pilot deals with the yard operations (see Figure 1) and involves the interaction of the storage equipment – Reach Stacker (RS)-, with the interconnection equipment -Terminal Trucks (TT). It has been implemented in Noatum Container Terminal Valencia (hereinafter, Noatum).

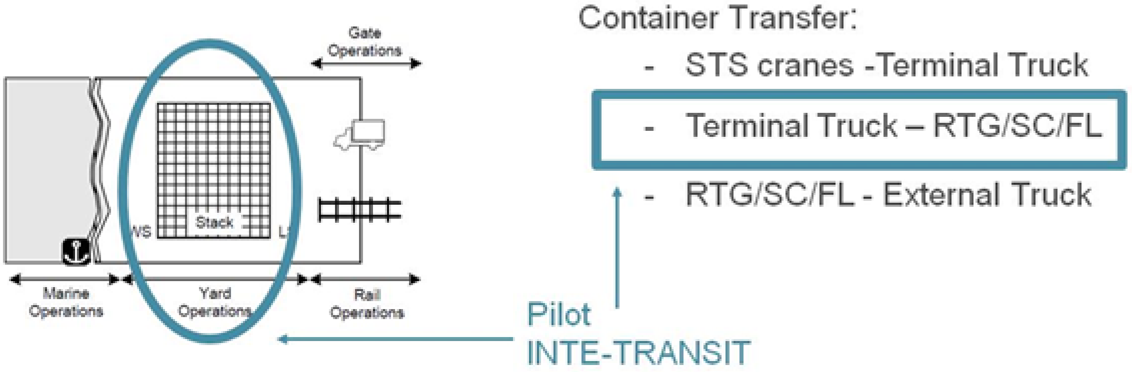

Figure (1) Operation areas for the generic terminal (Valenciaport Foundation based on [5])

Figure (1) Valencia Pilot dealing with yard operations

In order to understand how the Valencia Pilot works, it is important to bear in mind that the ITMS interacts with a client terminal hardware solution provided by the Valenciaport Foundation and Noatum, hereinafter called the Valencia Solution. The Valencia Solution is responsible for capturing and transmitting the necessary data about the equipment status and positioning. For this purpose, it integrates DGPS and RFID technology, as well as some interface devices such a screen to display the job orders.

1. The first phase tackles the Intra-Terminal Truck Positioning System (TPS), specifically:
   - The decision-making regarding the TT assignment depending on their proximity to the target container.
   - The temporary linkage of the target container identity (ID) to the identity of the TT transporting that container.
2. The second phase of the Valencia Pilot tackles the Container Positioning System (CPS), specifically:
   - The transmission of the target container ID from the TT transporting it to the RS assigned to stack it
   - The target container positioning in the stack.

1.a: The decision-making regarding TT assignment depending on their proximity to the target container.

The first part of the Valencia Pilot for the truck positioning automates the operational decision-making of TT assignment depending on how near they are to the target container, thus minimising the distance travelled by the TT fleet. This part of the Valencia Pilot consists of the following steps (Figure 2):

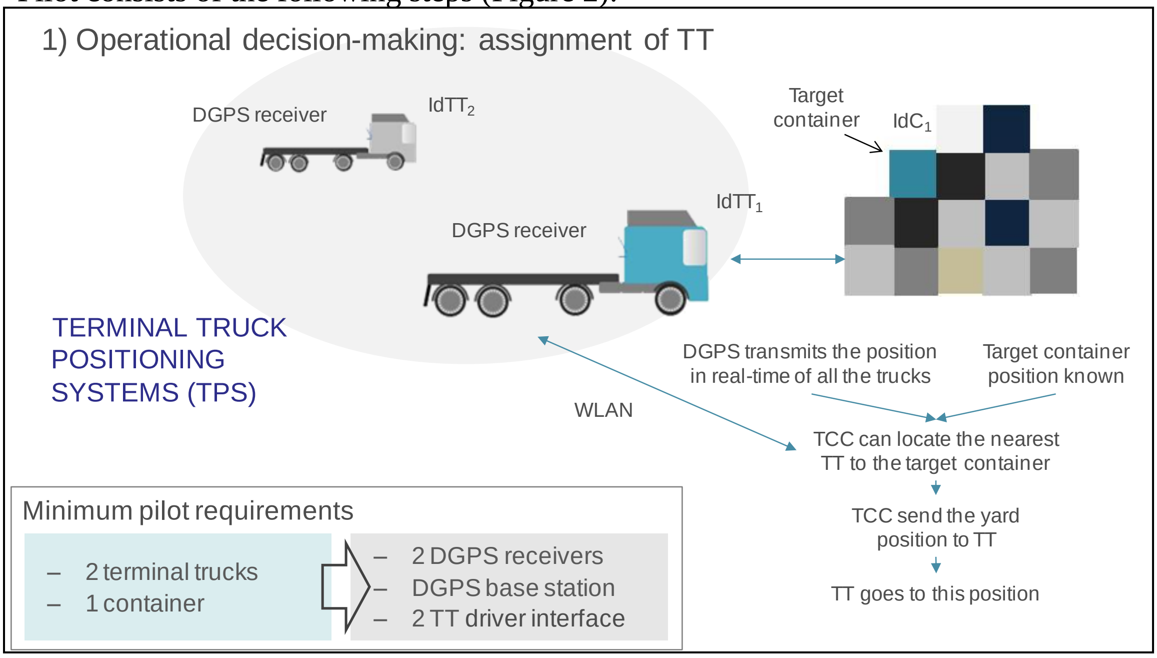

Figure 2 Decision making: assignment of the TT

- (2 or more) TT are fitted with a DGPS receiver and a screen (integrated in the Valencia Solution)
- The DGPS receiver transmits the TT position in real-time to the ITMS

- The ITMS manages that information in order to identify the closest TT to the target container (whose position is also known by the ITMS) and assigns it to carry out the operation.
- The ITMS sends the job order to the assigned TT (position of the target container)
- The ITMS updates the status of the TT (now assigned, previously free)
- The assigned TT executes the job order (goes to the target position)
- The status of the TT can be: free, assigned or loaded.

1.b:Temporary linkage of the target container identity (ID) to the identity of the TT transporting that container

The second part of the Valencia Pilot for the truck positioning automates the linkage of the target container identity (ID) to the identity of the TT identity transporting that container, improving the traceability of the container inside the terminal facility. This part of the Valencia Pilot consists of the following steps (Figure 3):

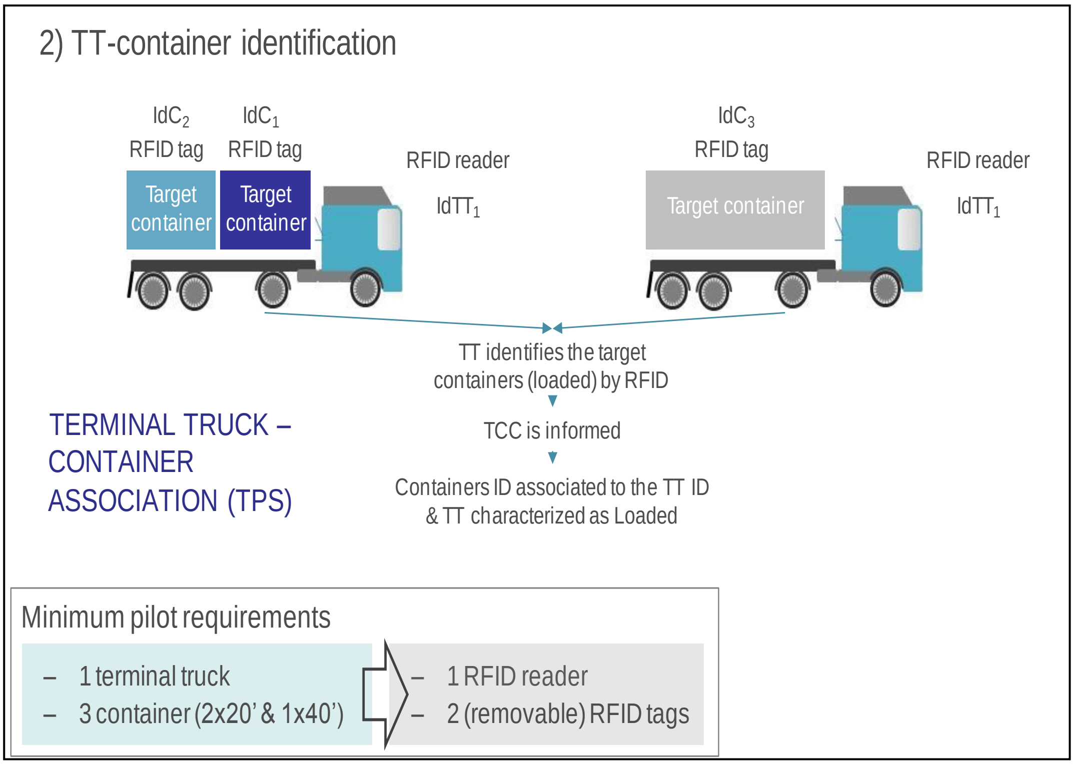

Figure (3) Temporary linkage of the target container ID to the TT ID which transports it

- The assigned TT is fitted with an RFID reader (integrated in the Valencia Solution)
- The target container is provisionally fitted with an RFID tag and the tag is temporarily linked to the target container ID
- The RFID reader of the TT identifies the target container and transmits this data to the ITMS

- The ITMS links the target container ID to the relevant TT ID
- The ITMS updates the status of the TT (now loaded, previously assigned)

2.a: Transmission of the target container ID from the TT transporting it to the RS assigned to stack it

The first part of the Valencia Pilot for container positioning automates the transmission of the target container ID from the TT transporting it to the RS assigned to stack it, preventing errors and guaranteeing the traceability of the container inside the terminal facility. This part of the Valencia Pilot consists of the following steps (Figure 4):

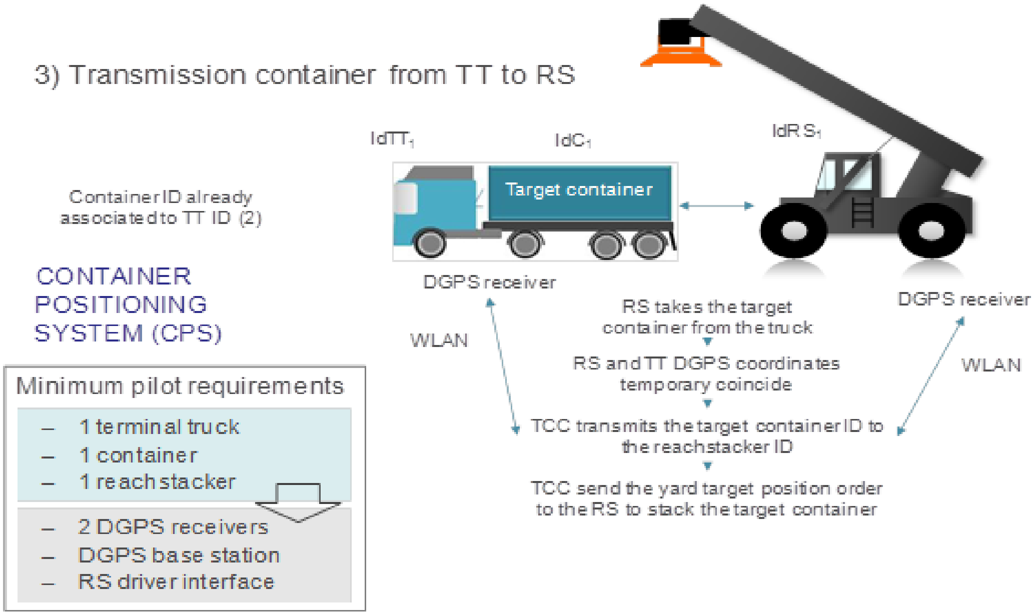

Figure (4) Transmission of the target container ID from the TT transporting it to the RS assigned to stack it

1. The target container ID is previously linked to the TT transporting it (part 1.1.b of the Valencia Pilot).
2. The TT transporting the target container is fitted with a DGPS receiver and a screen (integrated in the Valencia Solution).
3. The RS assigned to the operations is fitted with a DGPS receiver, a CAN Bus reader, an RFID reader and a screen (integrated in the Valencia Solution).
4. The ITMS sends the TT transporting the target container and the RS assigned to the operations their respective job orders (target position for the target container).
5. The TT transporting the target container and the RS assigned to the operations go to the target position in order to execute their respective job orders.
6. The DGPS receiver transmits the position of the TT and the RS in real-time to the ITMS.
7. The RS assigned to the operations takes the target container initially loaded on the TT.
8. The CAN Bus reports to the ITMS when the RS twistlocks are closed.
9. The ITMS saves the TT and RS position when the RS twistlocks are closed.

10. The ITMS links the target container ID to the RS and releases the TT using the temporary “coincidence” of coordinates (X, Y) of the RS and the TT on the terminal map.
11. The ITMS updates the status of the TT (now free, previously loaded) and the RS (now loaded, previously unloaded).
12. Additionally, since the RS is also fitted with an RFID reader (integrated in the Valencia Solution), the target container ID can be double checked by a process similar to the one described in section 1.1.b.
13. If the double check shows that the container being stacked differs from the target container, the ITMS shows that there is a situation requiring attention.

    2.b_Target container positioning in the stack

    The second part of the Valencia Pilot for container positioning automates the target container positioning in the stack, preventing errors and guaranteeing the traceability of the container inside the terminal facility.

    This part of the Valencia Pilot consists of the following steps (the reader is referred to **Error! Reference source not found.**):

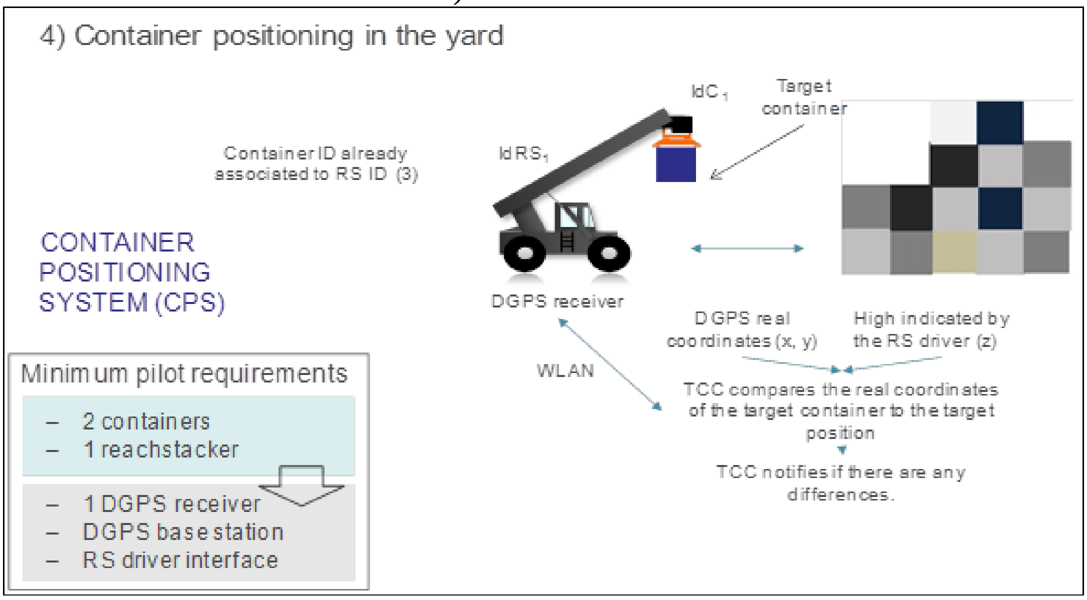

Figure (5) Target container positioning in the stack

1. The target container ID is previously linked to the RS loading it (part 2.a of the Valencia Pilot).
2. The RS assigned to the operations is fitted with a DGPS receiver, a CAN Bus reader and a screen (integrated in the Valencia Solution).
3. The RS assigned to the operations has already received its job order regarding the target container from the ITMS (target position for the target container) (part 1.2.a of the Valencia Pilot).
4. The DGPS receiver transmits the position of the RS in real-time to the ITMS.
5. The RS releases the target container in the target position in the stack.

6. The CAN Bus reader reports to the ITMS that the RS has released the container: twistlocks opening and Z coordinate.
7. The ITMS saves the coordinates (X, Y, Z) of the RS spreader when it has released the target container.
8. The ITMS calculates the position in the stack relating to those coordinates.
9. The ITMS compares the final position of the target container in the stack to the target position.
10. If both positions agree, the ITMS links the target container ID to that position in the stack and releases the RS.
11. The ITMS updates the status of the position in the stack (now occupied, previously free) and the RS (now unloaded, previously loaded).
12. If the final position in the stack differs from the target position, the ITMS shows that there is a situation requiring attention (back to step 10).

ITMS VALENCIA PILOT TERMINAL

The client terminal hardware designed for the Valencia Pilot consists of several interconnected modules designed to allow the accurate and efficient operation of the solution. Those modules have the following features:

- RFID technology for detecting and identifying containers. It is deployed with two parts: a fixed part installed in TT and RS (RFID reader and antennas) and another installed onto containers (RFID tags). An important part of this pilot is to evaluate the technology and test the resulting performance of this approach. This technology is already in use in these environments, albeit not for these kinds of tasks.
- GPS location technology. This is used to pinpoint the location, at all times, of the equipment, TT and the RS involved in this pilot. It is also used to establish the location of containers that are left in the yard. This is a mature technology widely used in these kinds of environments.
- INTE-TRANSIT Management System. It is a high-accuracy client-server system, suitable for improving the efficiency of port terminals, such as the Valencia port terminal, through enhanced monitoring of the containers as well as of the yard equipment (trucks, straddle carriers, reach stackers, etc.). It provides logistics support and intelligence to this test. This is a new management system which requires the deployment of a new communication protocol for the interconnection of on-board systems and the Central Management System.
- Wireless Communications. An essential part of this project. The solution proposes the use of simultaneous communication paths, one of them being the proprietary Wi-Fi network already deployed by the terminal, and the other a new GPRS/UMTS connection provided by this pilot. It has been interesting to test how they can work concurrently in a real working environment, in order to evaluate whether or not it is worth maintaining both of them in the future.
- Touchscreen terminal. The pilot uses a Touchscreen terminal to be able to view the orders that are assigned to the equipment and to facilitate the interaction between the operator and

the INTE-TRANSIT platform. It also combines all connections to the subsystems via a common Bus and performs the necessary computation in order to be able to transmit the relevant communication links to the INTE-TRANSIT platform using TCP protocols.

REQUIREMENTS OF VALENCIA PILOT MODULES

Apart from the requirements detailed in the description of the Valencia Solution modules, it also has to fulfill those described below:

- RFID:
  The scope of the RFID technology must allow identification of the container in the worst possible position, that is, when the container is loaded onto the platform with the RFID tag at the opposite end to the RFID reader.
  It must also be able to identify two 20' containers loaded in line on the same platform.
  Able to eliminate noise from other RFID tags which are inside the RFID reader range but which are not attached to the containers the TT is transporting.
  It is advisable to combine the RFID reader with a complementary detection technology that senses the presence of containers on the TT platform, such as a laser sensor. This allows the RFID technology to work more efficiently since it is not continuously reading and transmitting information; it only has to do so when the detection technology is activated.
- GPS or DGPS :
  All the equipment involved in the pilot has a GPS receiver installed which allows it to be located and, consequently, the container it is carrying which is detected by RFID.
  GPS or DGPS technology have to be accurate to 1 m (enough to differentiate between two consecutive container positions in parallel in a stack) and with a minimum reliability of 90% in determining the spreader position.
  This needs to be located on the spreader, to avoid using a gyroscope to convert the receiver coordinates to the spreader coordinates.
- CAN-Bus reader:
  J1939 CAN Bus reader to decode information on RS operation. It can detect boom extension and angle in order to calculate the Z coordinate of the spreader, as well as the opening and closing of the twistlocks, which indicates when the container is released.
- Transmission technology.
  As it is a vehicle, wireless technology is required for external communications.
  The pilot uses GPRS and Wi-Fi to be able to deal with any eventual location of the INTE-TRANSIT server (Internet or Intranet); both technologies are used to transmit the data collected by the different subsystems to the INTE-TRANSIT platform.
  Wi-Fi technology, plus complementary GPRS technology is used to solve the potential lack of Wi-Fi signal caused by the shadow projected by the stacks. Data acquisition time of less than 0.8 s and time between transmissions of less than 1.5 s.
- Touchscreen terminal
  Robust industrial touchscreen terminal (IP65), operating with Windows CE, 7 and XP.

VALENCIA PILOT RESULTS & LESSONS LEARNED

The main challenges tackled in the Valencia Pilot were:

- Valencia Pilot aimed to test the available technologies for container traceability and interaction with a central server that manages and controls operations.
- A DGPS system has been tested in real conditions inside a difficult environment (high bulk metallic canyons).
  To sum up, both AGPS (Assisted-GPS) and DGPS have been deployed to deal with positioning challenges in a real environment. As a result of preliminary tests, industrial AGPS has been chosen. In both cases however, a 2.5m error is expected most of the time.
  Position of the GPS antenna is a real challenge as far as the Reach Stacker is concerned because of its telescopic boom. In addition, a local DGPS station has been mounted in the terminal to improve local correction of GPS disturbances. A 1m error is expected most of the time. Nevertheless, problems are expected when the GPS antenna is enclosed between high metallic surfaces
- Analysing and selecting between active RFID or passive RFID.
  Active RFID has been ruled out for this pilot due to its inherent maintenance needs (batteries).
  One passive RFID tag per container is a low-cost solution and could be economically viable. As a result of attaching only one RFID tag to identify containers, more than one RFID antenna per machine was needed.
  Furthermore, the maximum range (more than 10 m) with RFID passive tags is reached with high power UHF tags (2W @ 865-868MHz).
  It has been demonstrated that low-cost RFID passive tags can be used for container identification. Once all the containers of the terminal are be tagged, simple software algorithms would refuse tags detected but not involved in operations. With the appropriate Management System, this working method will produce significant improvements in container traceability and intra-port movements.
- Testing the number of necessary tags and RFID antennas as well as their positions.
  More than one RFID antenna per machine is needed in order to identify a container with only one RFID tag attached.
  Furthermore, the RFID antennas should be attached to the machine in such a way as not to compromise its operation.
- An industrial Panel PC with a GPRS + Wi-Fi client has been connected to the external Server and internal Terminal Operator System (TOS), achieving uninterrupted, low-cost communications.
  The Wi-Fi layout could mean that there are “shaded” areas between metal canyons, which affects small moving machinery such as TT and RS. GPRS mobile communication, on the other hand, is available but could be expensive with heavy usage (due to data traffic charges).
  Therefore a dual parallel communication has been tested, with a GPRS router, an Ethernet switch and the Wi-Fi client working simultaneously.

- Translation to a cartographic system of new layers for container location. A GUI interface was proposed for human operators of the yard equipment that includes a cartographic representation of the locations involved in the process (target position, current position…).

CONCLUSIONS

The primary objectives of container tracking are physical localization and consequently terminal process optimization. At present, this inspection is mainly performed by human operators. Within the framework of the INTE-TRANSIT project, this paper presents the hardware solution adopted for the implementation of the client terminal in Valencia Port pilot, based on a low-cost implementation of (D)GPS and RFID technologies. The software architecture, including all architectural elements of the ITMS designed for the purposes of INTE–TRANSIT, is presented in detail, illustrating the open and modular system design principles followed. The principal functions of the ITMS are: obtaining and retrieving data (container identification, truck ID information, positioning data, control actions status) from all communication endpoints such as DGPS receivers, RFID readers, CAN Bus readers; managing the storage procedure of a container inside the storage areas of the port authorities; keeping a detailed inventory of the stored containers; and also providing a remote user with all this information properly displayed and visualised inside a GUI.

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