HUNTER – HYBRID UNIFIED TRACKING ENVIRONMENT

Real-time Identification and Tracking System using RFID Technology

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Abstract: This article presents a developed system that use RFID technology for trucks' cargo real-time tracking. RFID tags were settled at trucks' dump-carts and readers were spread throughout warehouses entrances, at the truck weighting scale and through unload platforms. The unload inspectors used robust PDA with camera, along with Wi-Fi access points installed in warehouses, to confirm the truck information and take a snapshot for future audits. A wireless broadband link was used to connect two weighting scale that are distant from the unloading area. All technologies communicate with a web-based middleware that manages all different devices. The system design is flexible enough to be used in very different applications like product process control, automated manufactory lines control, supply chain applications and others.

1 INTRODUCTION

The unloading of bulk cargo is a great security problem for companies that work with this product modality, since the unloading process consists in three tasks:

1. Full weight, which the truck is weighed with full loaded dump-cart;
2. Unload, which the truck goes to a designated site and unloads the product;
3. Empty weight, which the truck is once again weighed unloaded.

The amount unloaded by the truck is the difference between the second and first weight. Thus, if a load theft occurs in the period between the two weights, the company will not be able to know if the theft had occurred or even how much was stolen.

In some ports, the exporting companies' area is open to access by anyone or any vehicle, and the weight sites are approximately 2 kilometers far. This scenario makes the cargo theft possible by the following form: the truck is weighed fully loaded, and then it goes to an area outside the unloading zone; after that, it unloads the cargo at another truck, or exchange dump-carts, and then return to be weighed empty.

The estimated loss with cargo in bulk theft, at the studied company, is approximately 7% of its annual profit, which represents 750 thousand dollars. Based on that scenario, it was projected a Radio Frequency Identification (RFID) based solution to track the vehicles and works as an electronic seal at the trucks' dump-cart. So, the system control the sites where the truck is passing by, time from one point to another, and electronically detect a dump-cart seal violation.

All technologies used will be described to follow, including the managing application.

2 ACTIVE RFID SYSTEM

Present RFID systems consist basically of four components: an electronic tag, a reader, an antenna, and application software to process the data. When a tag approaches the antenna, the latter sends a signal to the reader with the tag identification. The reader receives the signal, and the information is sent to a computer executing the software. This software is normally a middleware application that processes the data packets and sends them to an end-user application or a database (Kim, 2006).

RFID tags can be active or passive. The active ones are self fed by an intern battery and the passive ones are fed with the energy from electromagnetic waves sent by the reader. Regarding passive tags, the reading ranges vary between 5 cm and 10 m. For the active tags, since they have internal battery, the reading range can reach distances in the order of 200 meters. Active tags can be connected to temperature, tamper and movement sensors, among others. For this reason, the active tags technology was chosen here for truck access control in warehouses and unloading area. In this case, the reader used operates in the UHF frequency range, at 433MHz to transmit data and at 915MHz to receive data from the tag, with 80 meters reading range.

To work as an electronic seal, a tamper sensor was attached to the tag. This sensor accuses “ok” status if its terminal were placed in short circuit and “violated” if the terminal were open circuit. This feature allowed the development of a tag model that could be fixed at a truck's dump-cart, seen in Figure 1. If occurs a tag removal attempt, the tamper sensor would detect and send a violation signal to the nearest reader.

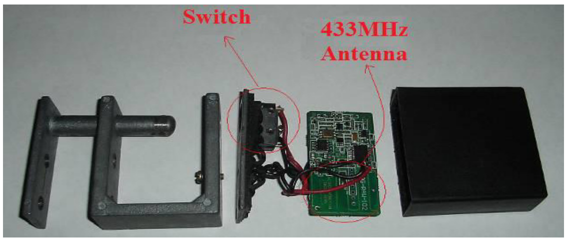

Figure 1: Active tag in a padlock shape with opening detector disassembled.

The main difficulty found in the tag design was towards the great difference between trucks used by the company, which made difficult to develop a single tag that could be fixed in each of them. To solve this problem, the tag was designed be similar to a padlock that can be fixed in any bar up to two inches thick, common in all kinds of truck. Therefore, it was possible to fix a tag in multiple parts of the truck. The violation detection of a tag is made throughout a small switch, that when the lock is closed, this switch is pressed and when the lock is opened, the switch is released. This switch was connected from two wires to the tag's circuit violation terminals sensor.

The adopted rule to install readers was: at each entrance and exit was installed a reader. For example, at the weighting scale platform were installed two readers, one at the entrance and another at the exit. At the unloading warehouses, one reader was put at each entrance/exit gate. All readers were connected by Unshielded Twisted Pair (UTP) cables Cat 5e. Warehouses and weighting scales were connected by multimode optical fiber cables due the long distance between readers’ installation point and the server. The optical fiber and the UTP Cat 5a cables create a local area network between all devices and the server which executes managing application. So, each truck's passage through a reader generates a data packet to the server with information containing the tag's identification, electronic seal status, timestamp and the identification of the reader that received the packet.

3 DIRECTIVE ANTENNA

The place where the tag is attached on each truck may vary depending on the truck’s dump-cart, and the material of it can vary between wood and steel as well. These variations can influence in the sensitivity of the tags, causing undesired tag readings outside the calibrated reader reading range. These readings happen when the truck is crossing in front of the warehouse entrance, causing unexpected alarms and making the system calls the security team unnecessary. To solve this problem, two resources were used: a directive antenna and the Received Signal Strength Indication (RSSI) feature of the reader (Foina, 2006).

This antenna will amplify the signal received in its directive lobule, sending a stronger signal to the reader in this case. But, if the signal is received outside its directive lobule, the reader will receive a weak signal (Balanis, 1997). The antenna used has an E-Plane and H-Plane beamwidth of 65 degrees at 3dB, circular polarization and 7 dBi of gain.

The RSSI feature of the active readers allows the measurement of the signal strength received by the reader. In the chosen equipment, the RSSI is an index from 0 to 255, where a higher value means a stronger signal.

With the RSSI and the directive antenna, the software can analyse the RSSI to check if the tag is behind or in front of the antenna. The directive antenna was installed behind the reader, facing to the warehouse door, approximately 1 meter away according to the Figure 2.

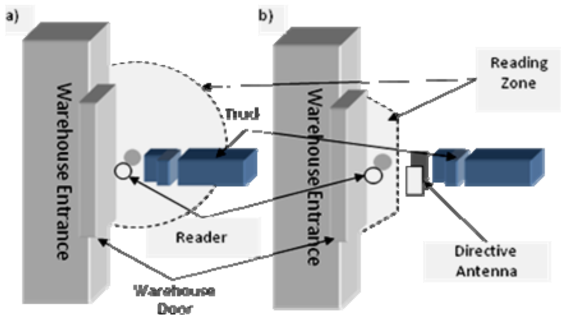

Figure 2: Aerial representation of the reading zone of both approaches, a) using the omnidirectional antenna and b) using the directive antenna.

When the tag is close to the door, but behind the antenna, the RSSI index will be very low because the tag is not in the main lobule of the antenna. When the tag is positioned between the door and the antenna, the RSSI index will be much higher than if measured in the same position with an omnidirectional antenna. This enables the middleware to make the decision of whether or not granting access into the warehouse.

4 MANAGING APPLICATION

The managing application developed, called Hybrid Unified Trekking Environment (Hunter), controls the unloading process information over the monitored vehicle. Every truck is treated by the system as an event queue to be executed. Inside the system, every truck's passage through an entrance/exit is an event. Full weight, unload and empty weight are examples of events to be executed by the truck. Thus, in the system, each truck has a state within a finite state's machine. Through received events by that truck, it registers exactly in which stage of unloading flow the truck is in real-time. In other words, the trucks in movement inside the area are treated as independent threads in the system, which is initiated when its tag passes by the weighting scale to capture the full weight, generating the first event. When these threads are created, a task queue at the data base is created as well, with all the tasks the truck must accomplish along the process, such as: weighting scale entrance for full weight, full weight capture, weighting scale exit, unloading area entrance, etc. While the truck moves and generates the events, these are interpreted by the system and converted into its respective tasks, and thus they are removed from the task queue and inserted in the journal table. In case the tasks orders are not obeyed, an alarm is generated on the system operator's screen.

The system graphical interface shows the number of trucks on each state of the unloading process, seen in Figure 3. The numbers of trucks in the lines between each state are showed as well. So, there are five states presented in the interface: Full weight capture, Unload line, Unloading process, Empty weight line and Empty weight capture. Through the graphical interface, it is possible to see the trucks that are in this state and how long they are there.

The application was totally developed in Java, being a part of it monolithic and a part in form of a web-base application. It is executed by a Tomcat application server and connected to an Oracle 9i data base with features of advanced task queue. As different technologies are used, the managing application was developed with modules, divided in three layers (Chen, 2003).

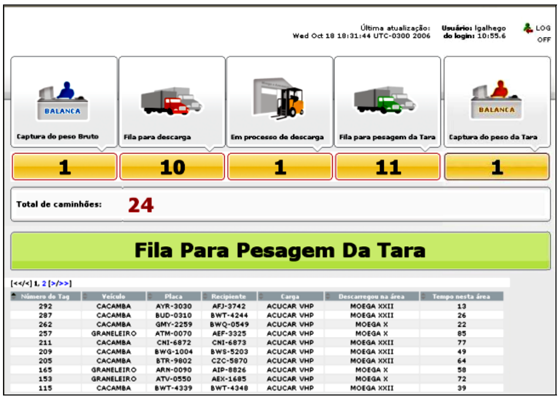

Figure 3: Hunter's screenshot showing the number of trucks in each state.

The first system layer, called Device Management Subsystem (DMS) is the layer responsible for the connection between the physical device, in this case RFID readers, and the system engine for process control, times and alarms, called here as Core. The DMS stays waiting for a package at the serial port or at the Ethernet connections, and when it receives a data sent by any device, it interprets the information and generates a message in Extensible Markup Language (XML) with information about the devices positioning, the name of the place where the tag was read and details about the truck which has read tag attached. to be sent to Core. DMS is a middleware, connecting different devices in the system at the same time, and allow new devices to be connected to the system without any change in the source code of the application.

The Core has a servlet that receives the XMLs from DMS and inserts them into the data base. When this insertion is made, the table where the information is stored has a trigger that initiates all the data analysis process, such as the alarms that can be generated due to this event or updates on truck's state in the unloading process. Connected to Core, there is the interface layer with two other modules, the graphical interface and the legacy integration systems. The first one is responsible for presenting information on the screen, such as alarms, navigation maps and reports. The second module is responsible for sending information to the company's legacy system, updating the warehouse stock, linking timing information and alarms generated to the company's Warehouse Management System (WMS).

All communication between system modules is made through XML messages and all system graphical interfaces are web-based, allowing its access from any computer without needing specific application installation, just a conventional web browser. The integration of the managing application with the company's corporative systems is made through recorded text files containing the XML messages in a shared directory due limitations of the company legacy system.

5 CONCLUSIONS

Despite the difficulties installing a wireless network and an optical fiber network in old warehouses, and placing sensible radio frequency equipment exposed to weather hazards, it was possible to install successfully all equipment and do their calibration. The server applications behaved correctly when were placed an amount of 200 trucks simultaneously circulating around the area and unloading the cargo.

Some unexpected problems happened and they were solved. The switch installed inside the padlock tag changed the inductance of the 433MHz antenna, so the internal organization of the tag was changed to keep the antennas as far as possible from the switch. Sometimes the truck parks in front of the reader, generating many readings of the tag, but sometimes the readings happed before the truck left the place. For this reason, filtering controls were implemented inside the DMS to avoid generation of fake alarms.

The system helped the company management and security. With the additional information generated by the system for the logistic department about the weight, unload time statistics, and the number of trucks in real time in each stage of the unloading process, it was possible to optimize the trucks' line, reducing the wait in line and therefore, reducing the average time of the unload process from 50 minutes to 30 minutes. The installation of RFID padlock tags in the trucks reduced in 60% the load theft in the port area and allowed the security team to find out points of vulnerability of the previous system and to detect the majority of the truck drivers corrupted by the theft group.

This same system showed flexible enough to be used with other RFID technology and applications, like passive tags to control automated manufacture lines, supply chain pallets and forklifts. In this case the application will control if the item pass through all the phases in manufactory line, from the beginning until the expedition. Can control who was the forklift operator and how long he took to move the products from one place to other. So the product will be tracked, supplying information about the storing and movement time, and the forklifts will be tracked as well, supplying information about the efficiency of the forklift operator and generating alarms if he does something wrong.

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