THREE-LEVEL RFID SYSTEM FOR ARCHITECTURAL CONCRETE PANELS TRACKING

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ABSTRACT: Tracking of goods in production and distribution lines is required by manufacturers, retailers, and customers, as well. Companies usually control the quality of their production in the manufacturing phase, but products can also be controlled along the distribution and transportation steps, before they are delivered to customers. The main objective of the project described on this paper is to develop a tracking system for architectural concrete panels. The system should enable the traceability, both downstream, allowing to know the origin of the panels and which processes were followed for any panel installed in a building, and upstream, so it is possible to further analyze the processes followed by the panel to be installed, including distribution and transportation. Therefore, the planning can be performed for optimizing processes and resources, and achieving an appropriate distribution of the timing, costs, etc. An auto managed three-level based RFID system is proposed in this paper in order to provide an efficient solution for the real-time monitoring (RTMS) of special loads, such as architectural concrete. The solution has been implemented by means of RFID passive and active tags and wirelessly communicated readers, corresponding to three levels of the supply chain. In the highest level, a wireless network connecting all the readers based on ZigBee technology has been implemented. This network is also connected to a GPRS system. Thereby, the main advantage of the proposed system is its ability to provide real-time localization of products (RTLS) all over the world.

Keywords: *Concrete, Panels, RFID, Active Tags, Sensor, WSN, GPRS, ZigBee.*

1. INTRODUCTION

In the dynamic and ever changing world we are living in, companies which are able to deliver products in a faster and better way will have more possibilities of success. Tracking of each unit of product should be performed during the manufacturing and distribution phases. The condition and exact location of a product must be determined at any time. This process is a critical issue, in particular in case of handling special loads. The properties of special products, such as fragile ones, perishable goods, and those which are included in recognized groups of quality, i.e. materials used in building and construction, need to be preserved.

In general, the productive process is carried out in an environment where all the units inside are usually completely controlled. A good solution is using the technology applied during this step for the rest of the process, or else to introduce new elements providing a compatible solution for the production and distribution lines. In this last line is RFID technology, used for tracking individual units of product with passive tags.

The open issue of the traceability and the tracking of products can be solved in a simple and economic way by means of the RFID technology [1]. By means of this technology, a significant reduction in time required for processing the orders is achieved, and the errors in the ordering system are also minimized. Products are received from the manufacturers in pallets or containers and in the picking tasks non-homogeneous loads are obtained by combining different products required by supermarkets or small and medium stores [2]. The application of RFID technology in the distribution chain generates a high added value by the improvement of the process and the optimization of the available resources [3].

This improvement in the traceability and tracking of special loads is not only available for companies, but for customers too. In this way, the customer is able to know the real-time status of the product before its delivery, as well as its geographical location. On the other hand, by means of exhaustively monitoring products, it is easier to assign the responsibilities when they are damaged or altered during the production and distribution phases.

The ability of location and tracking requires dynamic and secure architectures for building flexible systems, so the position and situation of a product is exactly determined by the system at any moment.

In order to achieve these objectives, a development based on RFID technology deployed at three different levels is proposed in this paper. An RFID system, which is able to support active and passive tags and managed by a middleware capable of correctly process all the generated data, is used for tracking every product from its manufacturing till its final location, including transportation and installation.

3. SYSTEM DESCRIPTION.

The tracking system must control the location and condition of any product at any time and must assign it a destination along the distribution chain. The proposed method is divided into three levels, as it is shown in Figure 1.

The first level is formed by the products themselves and/or the boxes where they are. The second level corresponds to the pallets of the product boxes that can be non-homogeneous. And finally, the containers capable of transporting a number of pallets inside constitute the third level.

The passive tags attached to each unit of product are part of the first level. They can communicate to the antenna located closer to its position, using the energy generated by the antenna. No additional logics are required for these tags, as their only task is to send their own identification codes to the antenna.

The active tags, as the ones shown in Figure 2, which are part of the second level, include the whole information of the pallet and the products contained on it, and they may also have sensors to get the data related to the environment where the pallets are going by.

Comparing both types of tags; the active ones have the advantage of a larger reach range and the possible use of sensors, whilst the life of the batteries is an important disadvantage. Thus improving the life of the batteries and reducing the power consumption of the tag for an optimal operation can be a good solution for the tracking and storing of products within the production and distribution lines.

The maximum distance covered by active tags is about tenth of meters when using simple readers that are more expensive, but nevertheless very reliable. However, for reading passive tags the practical range never goes over a couple of meters.

Fig. 1 Three-level tracking system.

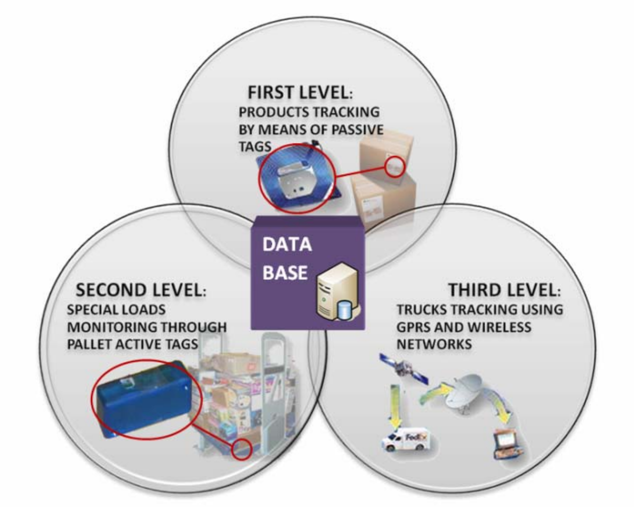

Fig. 2 Active tag in a pallet.

Furthermore, reading all the passive tags in a pallet usually requires going through a reading arch with several antennas. With the use of active tags, the tracking and control of the pallets of special products within a broad area, like a warehouse, is possible with a reduced number of antennas.

At the moment, there are Classes 1 and 2 EPC-type passive tags, active tags which can integrate sensors, and even manage the connection among several of them. They can be considered as elements of a Wireless Sensor Network (WSN) [4]. An interesting application for this type of sensors consists of making compatible its characteristics and the optimization of the batteries' life to enlarge its operational time.

The system collects all the information from the passive tags through the corresponding readers. This information is stored on the second level active tag. For example, in the picking processes, each pallet can be made of different product units, layers of the same product, or any other option for mixing the products in order to complete specific orders. All the information about the different products is stored in the active tag. In this way, the contents of pallets can be verified along the logistics chain, by contrasting the information of product tags with that of the active tag in the pallet containing them.

In the third level, the readers manage all the information regarding the container by means of reading or writing the whole set of active tags inside it. They communicate to each other using a IEEE802.15.4/ZigBee wireless network [5].

Every element of this network can be located inside a container-type load unit. These units have a double mission: on the one hand, they control the active tags which are stored inside them (pallet level); and, on the other hand, they are able to communicate to other similar units within a range of about fifty meters, establishing a radio network that can cover a broad space (like a warehouse, a ship, etc.) [6]. This network is managed by a "Personal Area Network (PAN) Coordinator", which should update the information of the units that are included in the network and the products combined for each unit. As this coordinator is connected to a GPRS module, it is capable of sending the information in real-time, so that the status of the load is available in the logistics base. Besides, its exact position is determined continuously. The tracking on land, at sea, or even by air of the load and its contained products can be globally performed this way.

4. SYSTEM IMPLEMENTATION

Once the theoretical model of the system has been presented, this section describes how the real system has been implemented.

The passive tags can be a good solution for tracking products along the distribution process; however, they lack the advantages of the active tags in important aspects such as the reach, considered as the distance to the antenna.

As previously mentioned, active tags are used in the second level. These tags contain information related to all the products on a pallet. Initially this data consists on the EPC identification of the products. Additionally, the position of the different layers of products in the pallets, created during the picking, can be added. As well as other data provided by sensors that can be incorporated in the active tag. Any problem in the picking process along the distribution chain will be recorded in the active tag, but also in the computer system.

The electronic components used in these active tags have been especially selected to reduce costs and power consumption. Basically, the active tags have two main components: a microcontroller and a transceiver for RFID communication. The PIC16F819 microcontroller has been specifically selected due to its low power consumption and its simplicity. The NRF905 RFID transceiver made by Nordic was selected because of its ease of configuration, and its good reach for its reduced power consumption. Battery life is also increased by always having the microcontroller in a low-power mode and switching to high-power only for operation. These readers can also be interconnected; so, on one hand, they check the content of a container; and, on the other hand, they constitute a network of readers. Therefore, these devices act like smart tags (level 3) for identifying containers while performing as readers for tags of level 2.

Basically, the Level 3 nodes, as in the case of the active tags, are composed of a microcontroller and an RFID transceiver. However, in this case power consumption is not such a limiting requirement as batteries can be much bigger than for active tags and containers are not in transit for long periods of time. For the applications considered here a good range was considered to be more relevant, both for the RFID transmission and for the creation of the ZigBee network.

Several sensors have also been included in the active tags to get information related to the environmental conditions of the pallet. In this first prototype, only temperature and humidity sensors have been implemented.

In the third level, pallets are grouped together and an active tags reader can access all the pallet tags at the same time. Pallet grouping is usually done inside containers, so a device like this third-level-tag can control each container.

The RFID transceiver used here is the same previously described for the tags. In this case, it has been configured using high transmission power in order to provide the system with the acceptable reach. Nevertheless, the microcontroller is not a PIC in this case. The module selected to create ZigBee networks is the JN5139 model by Jennic. This module has a microcontroller which acts as the device main controller.

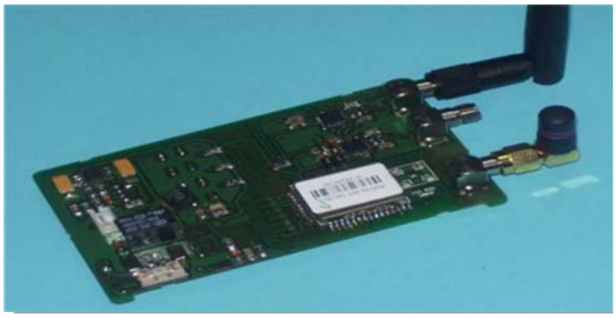

Fig. 3 RFID reader for active tags with ZigBee connection.

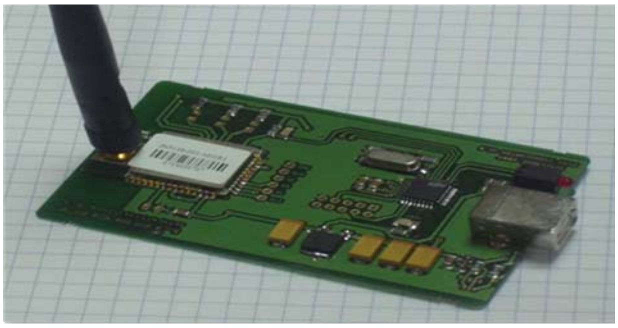

Fig. 4 ZigBee PAN Coordinator.

The reach of 3-Level devices depends on the transmission conditions: in open field, it is about 8 meters for the RFID readers; however, the ZigBee connection allows a distance of up to 50 meters between the antennas of the modules. This distance can be greatly increased at the cost of reducing battery life. The final layout of the RFID reader with ZigBee capabilities can be observed in Figure 3. Due to this limited range, a Multi-Hop network of readers should be established in order to communicate with the RFID agent core, which is the so-called “PAN Coordinator”. The final layout of this module is shown on Figure 4. It is equipped with an additional port, for connecting to the computer through an USB bus, and it manages the communication among all the modules.

Sometimes, the ZigBee network cannot be directly connected to a computer. In these cases, the ZigBee coordinator is connected to a GPRS module that can communicate to the coordinator over big distances in real time. By using this module, it is also possible to indicate the GPS coordinates in which the load is located, so the traceability data are added to products information. The GSM/GPRS communication module selected is the GE863-GPS model by Telit, because of its reduced power consumption, small size and weight.

5. APPLICATION

In order to test the applicability of the designed active tags, an important application for the proposed traceability system is the manufacturing of prefabricated concrete and cement, mixed up with glass fiber (GRC), and its onsite installation in a building. The life cycle evolution of the architectural concrete panels can be individually tested. This will include: manufacturing process, factory storage depot, transportation to building work, site assembly, and environmental conditions during its first years, once installed in the building.

The tracking system covers the whole process, as shown in Figure 5. The technical office generates all the information concerning the production works to be included in RFID tags, in order to track the panels in the subsequent stages. Once at the factory, a passive tag is embedded into the panel on the labelling place. As in the previous application, this constitutes the first level, so that they can be individually tracked, using a passive RFID reader, as the one shown in Figure 6.

Before delivering panels to customers, they are grouped together into special containers, constituting the second level. In these containers, an active tag is attached. In order to make the tracking and positioning available on the factory storage depot, which constitutes an area of about thousands of square meters, active RFID readers, as the ones described before for the passive tags, are installed (see Figure 7). By placing these readers at different positions within the storage area, the position of each panel can be known at every time. Readers act individually, using a presence detector, and communicate using the ZigBee network previously described. Active tags also storage useful information for process optimization, cost allocation, etc. As in the application for the bottling company, there is also an order dispatching reading arch, ensuring the reading of all panels on a truck and allowing the automatic generation of the shipping order for the carrier.

This complete traceability system enhances the management of the transport to the building work and assembling on the building structure as shown in Figure 5.

Results show a drastic reduction of errors percentage in panel identification, from the previous 30-40% to the current less than 1%. The high speed in the panels searching tasks within the storage area, achieved by the new system, allows a flexible and agile dispatching process.

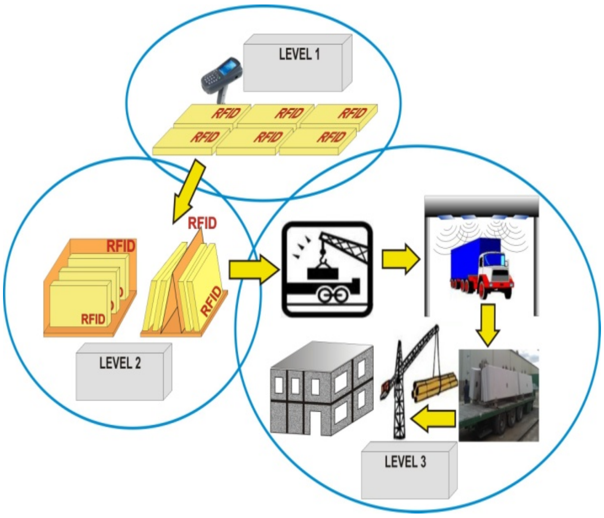

Fig. 5 Application of the proposed system to concrete panels manufacturing.

Fig. 6 Passive tag and RFID reader implementation.

Fig.7 Implemented RFID solution in the manufacturing company

Active tags contain useful information about the assembling process of panels, which is very useful for the final customer.

6. CONCLUSIONS

Most companies need their products to be monitored during production, storage and distribution. Sometimes, this monitoring does not only include its location and real-time working, but also the capability to get information about the physical situation of the products. Customers can also use the system to collect some relevant information about the products they buy, and check if they have correctly received their orders before opening them.

The application of three different levels of identification and wireless communications, like passive and active RFID systems and ZigBee networks, improves the performance of extensive tracking for special loads. Besides, an absolute traceability and visibility – which includes real-time location of products - can be obtained during distribution or storage and the ordering processes can be effectively automated.

The proposed system provides a good reliability and quality control as it is even able to detect errors in any point of the chain. It has been implemented for the location of panels by means of passive tags. Special data collection using active tags and the capacity to monitor the whole supplying chain in a company for manufacturing concrete panels is also provided by the traceability system.

Achieved results by means of the proposed system application have been very encouraging. The radical decrease of the number of errors, from the initial 15 or 30% going down to less than 1 percent in both cases, has also been managed. Besides, the technical office and order dispatching tasks are now done in a faster, more efficient and flexible way. In addition, the data collected by the active tags, which is also available for the customer, is an additional service provided by the system.

Our future work will consist on improving the procedure for sending the load status and its real-time position in bigger geographical areas, like the ones within the production center and the delivery of the products to the customer. A graphical interface, based on the use of Google Maps, is intended to be designed for the real-time location of products.

REFERENCES

[1] Glidden, R., Bockorick, C., Cooper, S., Diorio, C., Dressler, D., Gutnik, V., Hagen, C., Hara, D., Hass, T., Humes, T., Hyde, J., Oliver, R., Onen, O., Pesavento, A., Sundstrom, K. & Thomas, M. (2004). "Design of ultra low cost UHF RFID tags for Supply Chain Applications". *IEEE Communications Magazine*. No. 8. pp. 140-151.

[2] Wong, C.Y. & McFarlane, D. (2007). "Radio frequency identification data capture and its impact on shelf replenishment International". *Journal of Logistics: Re-search and Applications* Vol. 10(1). March 2007. pp.71–93.

[3] García, A., Chang, Y. & Valverde, R. (2006). "Impact of new identification and tracking technologies in a distribution center". *Computers & Industrial Engineering*, ScienceDirect, Vol. 51(3). pp. 542-552.

[4] Baronti, P., Prashant, P., Chooki, V., Chessa, S., Gotta, A. & Fun Hu, Y. (2007). "Wireless Sensor Networks: a Survey on the State of the Art". *Computer Communications*. Vol. 30(7).

[5] ZigBee Alliance. (2008). ZigBee specification 1.0. http://www.zigbee.org. January 2008.

[6] Javed, K. (2006). "ZigBee suitability for Wireless Sensor Networks in Logistic Telemetry Applications". *Technical report*, IDE0612. Halmstad University. Sweden. 2006.