PROCESS OF DESIGN AND IMPLEMENTATION OF A DIGITAL TRANSPORT PALLET

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Abstract

Since the transport of goods was entrusted to third parties, there was a need to mark the goods. From the initially primitive methods to the present day, where the waybill plays a key role in transport logistics, the ways of freights significance have undergone significant evolution. One of the most important steps was, among others, the standardization of packaging and the appearance of EUR pallets. The introduction of IT tools, globalization of services including not only transport but also packaging management, storage services, redistribution of goods, insurance services and many more, create new development prospects. The logistic tools that are currently applicable to the expanding logistics area and the requirements are becoming insufficient. Thus, the industry is waiting not only for another evolution but more likely for a revolution. The change of the transport logistics model, in particular in the context of returnable packaging, resulted in the emergence of, among others, pallet pools on the market. New models, extended services and innovative economy 4.0 require new technical solutions. One of such solutions may be the introduction of a digital transport pallet. The assumption of this solution is a global exchange of information regarding the packaging along with the content, transport conditions as well as the current geographical position. The article presents problems resulting from marking goods, potential methods of freight monitoring, and proposes a new solution for permanent marking of transport pallets with radio tags. A built-in technology demonstrator was also presented.

Keywords: Pallet, RFID, monitoring, Industry 4.0

1. INTRODUCTION

With the development of transport and forwarding trade, there is a growing need for reliable monitoring systems for transported goods. The system is understood as an arrangement of elements having a specific structure and constituting a logically ordered whole. [1] The new solution must be adapted to the current market needs, which in the case of dynamically developing logistics is not a simple task.

For forwarders as well as recipients, it is important to have knowledge about the transported product at every stage of transport. This knowledge is not only limited to information where the transport is located but also about its conditions such as: temperature, humidity, lurches, and vibrations to which the product was subjected to. On the basis of this information, it is possible to determine whether the transport took place in accordance with the agreed conditions, thanks to which the recipient can be sure that he receives the product in a satisfactory condition. For this reason, the introduction of such systems will not always be satisfactory for a forwarding agent who will not be able to hide any unsatisfactory transport conditions. On the other hand, the entity responsible for transport will not be exposed to unjustified claims for unsatisfactory transport conditions.

The example described in the article [2] shows that almost 40 % of fruits and vegetables are wasted due to improper handling, storage, packaging, and transportation. Factors affecting the destruction of products include vibrations occurring during road transport on uneven roads. In addition, different types of fruit and vegetables must be transported at the right temperature and humidity. In the case of improper treatment, fruits

can completely break down or lose their nutritional value. Observation of these phenomena during transport is possible only with the introduction of advanced transport monitoring method. In the future, the data collected from transports will help implement new procedures for securing the freight. The use of monitoring methods alone is not sufficient, special attention should be paid to minimizing the damage of transported goods.

Scientific goal of this paper is to verify usability of sensors and coding systems for use in transportation and logistics. The paper is organized as follows: First, an outline of the current situation is given, and a disposition of the problems that occur as a result of the limitations of the current way of operating. Following, a description is provided of how these problems might be overcome if Digital Transport Pallets were used. Furthermore, our proposed solution is addressed and the demonstrator was build.

2. SOLUTIONS OVERVIEW

At the very beginning of trade development, primitive forms of recording basic information about transported goods were used, so-called “clay tokens” [3]. Currently, for this purpose, bills of consignments are used, which contains the necessary information about transport. The transport document according to the CRM convention is the proof of the contract of transport. There are different types of international bills of consignment depending on the type of transport:

- CMR, TIR Carnet - road transport;
- CIM (SMGS) - rail transport;
- AWB, MAWB, HAWB - aerial transport;
- Bill of Lading - marine transport.

According to the CRM convention (related to road transport), the bill of consignment performs the following functions: information, instruction, identification and evidential functions. It is stated that the lack of a bill of consignment does not affect the existence of the contract or its validity. However, a bill of consignment filled in accurately and correctly constitutes the basis for any complaints or claims. It is not uncommon to lose such a document. In the event that the new system would perform the same functions by storing information in the database, the chances of losing them while maintaining the paper form would be reduced.

With currently used implementations of pallet handling it is possible to partially automate the process by incorporating Optical Barcode Systems (OBS). The unique barcode is placed on every package transported and thus the package information can be read with network-enabled barcode scanner. The main disadvantage of this kind of solution is that the barcode needs to be scanned at several stages and then submitted to the system. This method is time-consuming and prone to errors. Another disadvantage is that the system only allows for discrete-time tracking. The OBS systems were deployed for many years proving its value, but the functionality of the system has reached its peak, mostly due to physical limitations of paper labels. Additionally damaging, or covering the label in reflective foil can lead to ineffectiveness of automated scanners and urging to manually enter the package number, which is time consuming and can lead to human-related errors.

Due to reaching maximum functionality of physical letter of transit, the need for an electronic transit letter (ETL) arises. Proposed electronic transit letter should be incorporated into palette in a way that provides firm placement and ensures safety of electronic parts of the device. Every transport letter should be marked by a unique, unchangeable and tamper resistant ID number, which can be read by everyone with an appropriate scanner. This ID will also be a database primary key, which enables viewing additional data for people involved in logistics.

Communication between ETL and a scanner should be done by a wireless manner to minimize time needed for scanning. There are many solutions considering wireless communications, which can be used for this application.

The challenge to develop a new transport monitoring method is to create an appropriate IT base. Anyone involved in a given transport should have access to the database, but only to some of its parts. Limited access would prevent unauthorized persons from accessing information, at the same time information that reaches a specific person or company will be presented in a transparent way without unnecessary data. An additional advantage of such a solution would be the possibility of creating a platform for information exchange, thanks to the introduction of limited editing capabilities by appropriate authorities, for example entering information about the status of goods, planned delays, damages, controls.

A factor that increases the difficulty in developing a reliable system is globalization, causing difficulties in introducing appropriate standards in different countries, especially when the type of transport changes, for example from a road to air. In addition, systems must comply with both international and national regulations.

Another challenge is a way of attaching ETL to the transported goods. In addition to groupage shipments during freight forwarding, the goods are permanently combined with the transport packaging. The use of standard packaging such as EUR pallets significantly facilitates transport logistics, reducing its costs. Therefore, it is advisable that the ETL is permanently attached to the transport packaging which is the pallet.

3. WIRELESS COMUNICATIONS

The increasing interest in Wireless Sensor Networks leads to extensive studies concerning its application in real world scenarios. This is due to flexibility in node design, wireless sensor networks combine large population of wirelessly connected sensor nodes. Every node combines distributed sensing and wireless communication, integrated in a single device. Currently it is possible to produce nodes, which can not only monitor the surrounding environment, but also can track and record all activities occurring during transport and logistics process, such as loading, unloading, storing etc. Due to existence of pallet pools where single pallet can be repurposed to enable transportation of different cargos, the node needs ability to be wirelessly reprogrammed with a set of rules according to type of goods transported.

Wireless sensor networks combine large population of wirelessly connected sensor nodes. Every node incorporates sensors for distributed sensing, radio transceiver for wireless communication and a power source such as a battery, all integrated in a single device. Device in question must be contained in a small form factor rugged enclosure in order to be applicable to pallet integration. Additional requirement concerning battery-operated wireless node is minimizing its power consumption to ensure proper operation during all of pallet lifecycle which is 33 handling cycles. Each handling cycle is an average of 15 pallet handlings. Each handling is a single lifting, movement and set down, assuming medium duty loads[4]. Also every node have to incorporate a power saving mode. This enables powering down certain types or all sensors when pallet is stored in a pool or it's used to transport goods without specific requirements such as temperature.

3.1. Types of short-range wireless communication technologies appropriate for use in logistics.

The most popular short range communication technologies are: WiFi [5], Bluetooth [6], RFID [7]. WiFi standard provides backbone for fast wireless communications, but implementations of this solution are energy consuming, due to fact, that the transmitter needs to be operating all the time, thus bigger batteries needs to be installed, increasing overall size of the device or diminishing expected battery life. This limitation can be addressed by using Bluetooth Low Power technology combined with mesh networking. [8]. There are also RFID[9] active tags, which can incorporate internal sensors and perform more sophisticated calculations, as well as being able to maintain low power consumption. Disadvantages of solutions given above is fact that they still need to rely on battery power in order to operate. On the opposite there are passive RFID tags, which can be powered by the scanner itself. Disadvantages of passive RFID tags are low computational possibilites and fact that it only can work as an idenifier. Due to the factors given above, RFID active tag was chosen for application in the ELT system. Low power bluetooth systems are also considered, especially during prototyping part. To test various communication techniques a system demonstrator is needed.

4. SYSTEM CONCEPT

The pallet marking system should contain all the necessary elements that allow the use of data in transport logistics. The main components will be: palette sensory elements, wireless data transmission elements, data processing system and information distribution. Data transfer schematic is shown on the **Figure 1.**

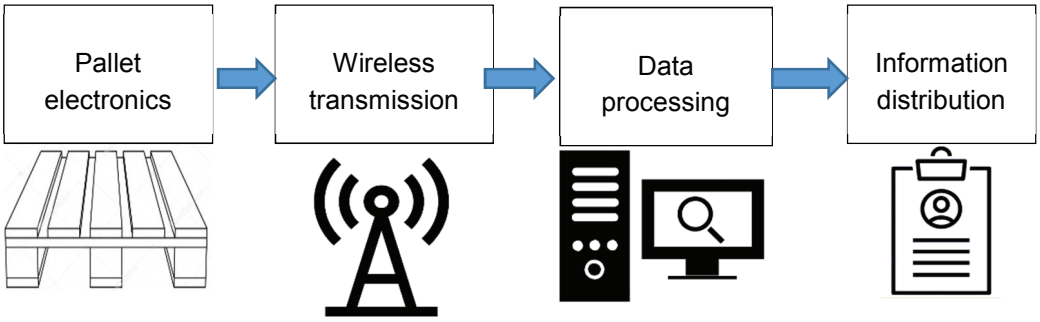

Figure 1 Data transfer schematic for pallet system

Palette electronic systems consist of measuring elements, data memory and wireless data transmission system. Additional elements such as antenna power supply and mechanical protection are dependant on the system version. In the absence of sensory elements, it is possible to use passive systems that transmit data stored in the memory without using an internal energy source. The elements of radio data transmission consists of a set of means and devices allowing to read data from the unit placed in a palette and transfer of informations to the data processing system. The data transfer can take place using various standards from RFID, through bluetooth, wifi, GPRS along with the use of Internet IOT devices. Then, in the Data Processing System, the information received is collected in an appropriate database. This database combines information about the serial number of the pallet with an electronic bill of lading. Information on transport conditions, the last known location of the goods and other events that have been registered in the palettes sensory systems are added to such a letter. The next task of the data processing system is the distribution of data in the form of dedicated reports. Such reports may be sent to shippers, goods owners, sender and recipient as well as to persons involved in the forwarding chain such as forklift operators or truck drivers. Information in the database can also be made available to state services such as the Customs Office, the Tax Office and others.Demonstrator

The demonstrator's construction was limited to the vibration sensor and the local information distribution system. Main components of demonstrator are shown on **Figure 2**.

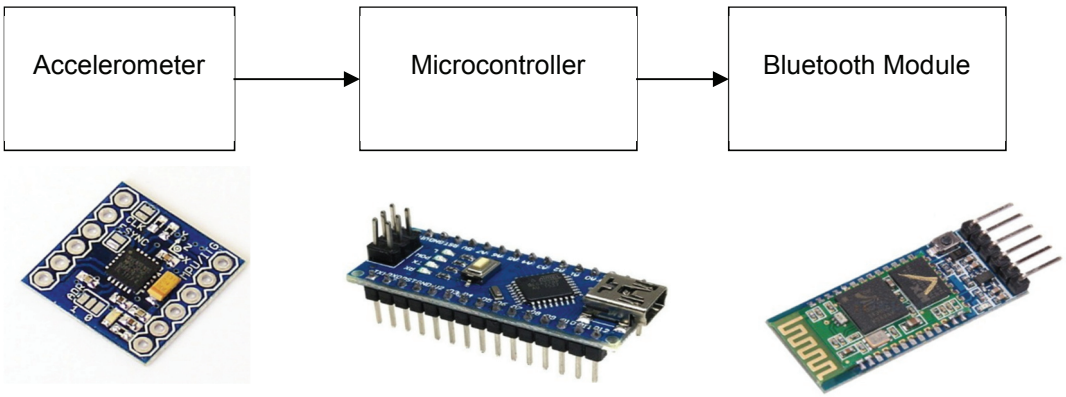

Figure 2 Demonstrators main components

Accelerometer made in MEMS technology measures vibration acceleration in 3 independent directions. In order to limit the power consumption of the system, system interrupts were used. The microcontroller remains in a low-power state until vibration is detected by the accelerometer sensor. Due to the generated interrupt, the sensor puts the microcontroller into operation. The measurements are taken and the results are saved in memory. In the case of Bluetooth connection, the results are also sent to the recipient (to the receiver). The lack of vibration causes the microcontroller to go to low-power mode.

The built-in demonstrator made it possible to carry out a number of tests, including estimation of electric power consumption, maximum ranges of radio transmission and values of accelerations occurring in the tranc- tor. The module was built in one of the cubes being part of the transport pallet construction. A hole with a diameter of 30 mm was made. In this hole the demagnetizer system was placed. Then the hole was closed with special plugs, protecting the elecronic system from atmospheric factors.

Figure 3 Installation of the demonstrator

The demonstrator was installed in a middle pallet support by drilling apropriate size hole and placing the device inside. Picture of the demonstrator being installed is shown on **Figure 3**.

The EUR transport pallet has been put into use by the selected recipient. Between transport cycles, measurable parameters were read during storage. An example of the course of the acceleration of vibrations caused by the process of transferring the pallet is shown in **Figure 4**. From the analysis of this course it can be concluded, among other things, that the acceleration impulses reach 1 g, which may pose a threat to some goods transported on a pallet. The additional time record also allows to identify activities that were the cause of excessive vibration levels.

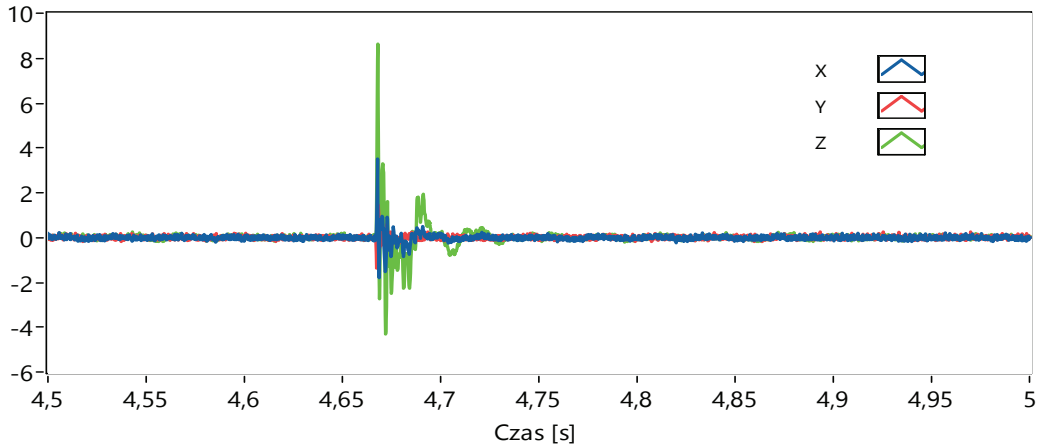

Figure 4 Example of acceleration caused by process of transferring the pallet

5. CONCLUSION

Such devices are needed for logistics and allow for cost reducing by managing means of transport on the basis of information received from system proposed. The assumptions made for the construction of a transport packaging system with identification systems have been tested in the demonstrator. The tests were limited to a limited extent, but the significance of these solutions in the field of transport logistics has already been

demonstrated. Demonstration device allowed to estimate the value of accelerations occurring during a wheeled transport. On the basis of the measured values, it is possible to determine the impact of vibrations that occurred during transport on the different type of goods. Immediate information about the transport points reached, such as warehouses, intermediate stations, sender stations and the receiver will allow optimization of means of transport in terms of costs, time of transport as well as transport conditions. As part of further research work, the problems of remote reading of identification numbers and also the development of sensory systems allowing monitoring of other parameters desired by shippers will be addressed.

REFERENCES

[1] DRABIK, Lidia and SOBOL Elżbieta. *Słownik Języka Polskiego PWN,* Warszawa: Polskie Wydawnictwo Naukowe, 2018. p.1360.

[2] SINGH, Vishal, HEDAYETULLAH, Md., ZAMAN, Parveen and MEHER, Jagamohan. *Postharvest Technology of Fruits and Vegetables: An Overview.* Journal of post harvest technology. 2014. vol.2, pp. 124-135.

[3] BUDJA, Mihael. *Clay tokens - accounting before writing in Eurasia.* Documenta Praehistorica. 1998. vol. 25, pp. 219-235.

[4] ANIL, S.K., RAY, C, KREMER, G. (2010*). Pallet life cycle comparison using LCA and multiobjective dynamic programming*. In 31st Annual National Conference of the American Society for Engineering Management. Fayetteville: ASEM, 2010. pp.514-521.

[5] YANG, Guang-Hua, XU, Kuang and LI, Victor. *Hybrid Cargo-Level Tracking System for Logistics.* In 71st Vehicular Technology Conference. Taipei: IEEE, 2010. [viewed 2018-10-25] Available from: DOI: 10.1109/VETECS.2010.5493655.

[6] RUIZ-GARCIA, L. and BARREIRO, P. and ROBLA, J.I. *Performance of ZigBee-Based wireless sensor nodes for real-time monitoring of fruit logistics.* Journal of Food Engineering, 2008, vol. 87, iss. 3, pp 405-415.

[7] ABAD, E., PALACIO, F., NUIN, M., GONZÁLEZ DE ZÁRATE, A., JUARROS, A., GÁMEZ, J.M., MARCO, S. RFID smart tag for traceability and cold chain monitoring of foods: Demonstration in an intercontinental fresh fish logistic chain. Journal of Food Engineering, 2009, vol. 93, iss. 4, pp. 394-399.

[8] YU, Chih-Min, HUNG, Shao-Kai and CHEN, Yu-Chih. *Forming mesh topology for Bluetooth ad hoc networks.* In Digest of Technical Papers - IEEE International Conference on Consumer Electronics. Hsinchu City: IEEE 2013 Pp. 123-124

[9] OH, Ryumduck, PARK, Jeyh. Development of Active Monitoring System for Intelligent RFID Logistics Processing Environment. In Advanced Language Processing and Web Information Technology. Liaoning: IEEE 2008. viewed 2018-10-25] Available from: DOI: 10.1109/ALPIT.2008.51.