RFID Application in Municipal Waste Management System

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Abstract

An integral part of the consumer unit's life cycle includes its disposal or disposal of the distribution packaging. RFID tag used to identify the product can provide identification of the product itself as well as the packaging. This information can be used in the waste selective sorting process with regard to the safe management of waste and to optimize its secondary use. However, at this time the implementation of the RFID tag to each consumer unit is still a vision for the future, the use of RFID technology in waste management is already a real issue.

Automatic identification and data capture of municipal waste containers emptying process can provide very useful information. Such information is important both for the customer who can be sure that he pays for the real services, as well as for the service providers, allowing them to easily and reliably prove the contractual service of the collection and treatment of waste.

This article deals with the application of RFID technology to identify the time and place of containers with municipal waste emptying and the benefits of the system based on this principle.

Keywords: RFID technology, waste management system, GPS, Internet of Trashed Things, IoTT

Introduction

Generally, waste management includes all activities related to the waste. Since the time when the waste is created, through the collection and transportation of the waste and the variety of possible modifications to the final use when waste becomes a raw material for further production or is utilized for energy production. Waste management includes also the waste disposal, when the unusable waste is deposited in a landfill or incinerated. In our paper we focus mainly on the "smart" technologies in systems of waste collection and transportation.

Vehicle tracking systems using GPS (Global Positioning System) and the use of auto-identification technologies for waste management are already being used in a wide variety of activities and cities around the world. The identification of waste containers based on RFID allows cities and municipalities to reliably identify individual containers and can help to develop recycling habits of citizens through various incentive programs. The incentive program may for example consist of discounts on waste disposal service for customers with a large proportion of sorted waste. Thanks to the automated identification of waste containers, the information and evidence about the frequency of containers emptying, or on the effectiveness of their collection system can also be obtained. Such information helps to optimize the number and location of collection points and also helps to properly optimize plans for waste disposing.

One of the current strategic goals of the waste collection and processing companies dealt with is the waste separation support with the increased awareness for the environment quality and gradually reducing waste disposal costs. Up to 30% of costs include fees for landfilling of municipal waste. Just removing a ton of bio-waste is only half as costly as disposal of the same amount of municipal waste. Therefore, it is desirable to sort waste as far as possible.

The Current Status and Related Cases in Czech Republic and Abroad

Nowadays, the automatic identification technologies have been applying in almost every field of human activity, including the collection and processing of waste.

Reis et al. (2014) describe the iEcoSys system (Intelligent Ecologic System) developed by the authors. It is a technological tool that identifies the waste produced individually, using RFID tags embedded in rubbish bags – the iBags. When depositing waste, the recycling center identifies and weighs each bag and the collected data is sent to a server system using ZigBee communication standard. When the information reaches the server system, it is inserted into the database

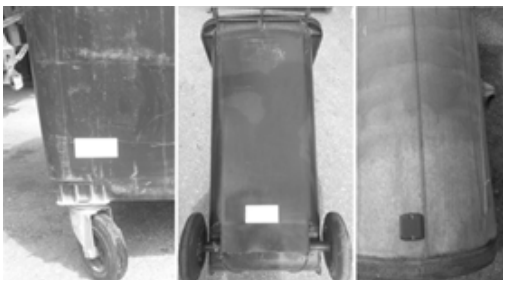

Fig. 1 RFID tags on plastic and metal container

Rys. 1 Znacznik RFID dla plastików i kontenerów metalowych

Fig. 2 Smart label for plastic waste collection containers design

Rys. 2 Naklejka dla kontenerów na odpady plastikowe

management system, making it possible to see the deposited waste in the iEcoSys internet portal, and even order new iBags.

Abdoli (2009) discussed some applications of RFID technology in Product self-management, with emphasize on municipal solid waste management as well as environmental implications of RFID.

However, AMCS has been offering RFID technology since 2003, to help municipalities and private waste-management firms in Europe and North America manage their pickup routes, as well as enable accurate billing and reject services onsite for unpaid accounts. The system employs 125 kHz low-frequency (LF) RFID tags.

Air-Trak's WasteConnect System is comprised of in-vehicle tracking units, a hosted network operations center, and a web-based management portal. There are options to add a Garmin display terminal and RFID capability in vehicles. The WasteConnect data center manages the entire data flow which is completely accessible to the customer through the WasteConnect Web Portal.

In Cleveland, RFID was part of a $25-million dollar solid waste modernization program, as is mentioned (Fickes, 2010). The tags links trash and recycling bins to owners, aiding management's efforts to cut costs and increase recycling. The RFID data identifies which households put out trash and recycling, which only put out trash, which only put out recyclables, and which left nothing at the curb. The RecycleBank program encourages households to recycle by rewarding them with points based on the amount they recycle.

The points are redeemable at local and national retailers, restaurants and grocery stores.

Some companies that deal with the collection of municipal waste have already implemented a solution using RFID technology to identify the time and place for dumping containers with household waste in the Czech Republic and Slovakia. For example, the STKO Company introduced a register of all the collecting bins in 1996. This solution was based on barcode identification and its scanning by handheld terminals TOYOTA DENSO BHT 8000 with application GBC STORE. The crew manually scanned a label which was in municipal waste container. After returning to the company grounds, the data was transferred to the information system and paired with information about client. They have had complete overview of what have been happening with their bin and what pay for. However, this system required a high proportion of manual labor and it was not totally conclusive and acceptable for invoicing. It was therefore replaced by a system of automatic identification using RFID technology.

This article describes RFID application which was implemented in Mikulov in Czech Republic in 2010 and in Piešťany city in Slovakia in 2013. This application combines using identification based on UHF RFID together with other smart technologies for improving the provided services.

Hardware and Software Solution

Given the characteristics of the surrounding operating environment of the system (everything is installed on the outer surface of the vehicle) the system has to satisfy the condition of high resistance and robust design.

RFID reader

The identification of the designated collection

Fig. 3 Industrial computer for data collection and processing
Rys.3 Przemysłowy komputer dla zbierania i przetwarzania danych

Fig. 4 SW application
Rys. 4 Aplikacja SW

containers itself is carried out by industrial high powered reader with adjustable power and special antennas. UHF RFID reader used in the described system is called Impinj Revolution R 420. The reader has four antenna connectors of which only two are used to connect to two linearly polarized UHF RFID antennas of the type H86-AD with the gain of 1,5dBi tuned for the frequency band 865–870MHz. High reader sensitivity of -84 dBm allows us to ensure high level or RFID tags readability. The reader power is adjustable in the range of 10 to 31.5 dBm so as to allow the precise identification of only the raised container and not the surrounded ones. Reader is together with other electronics placed in the anti-vibration box with the IP65 protection certification and dimensions 300x250x150 mm. The reader is powered via connection to the vehicles onboard electrical distribution system with 12/24 V converter, capable of supplying power of 15 W.

RFID tags

Two basic types of RFID tags are used for labeling of the collecting containers. Both operate at a frequency of 865MHz and meet the standard EPC Class1 Gen2. In the memory of each RFID tag is stored a unique identifier that identifies the container over the radio interface. The maximum reading distance for the described system is identical for both types of tags and is about 3 meters.

The RFID tag that is used on the plastic collection containers is a polyethylene film coated smart label. Application of the smart label can be done without any structural alteration to the body of the container. Placement is performed on the cleaned and degreased surface of the container simply with an adhesive, which is an integral part of the label. In the case of smart label the identification of the container can be also done via optical way based on the printed barcode or alphanumeric code.

For metal collection containers solid industrial RFID tag is used. It has a thickness of approximately 9 mm and is heavily coated with a layer of plastics to ensure a high degree of mechanical durability. This kind of RFID tag is attached to the surface of the collection container with the aid of rivets.

Industrial PC

Software system, as well as collected off-line data is stored on an industrial PC located together with the reader in water- dust- and vibration-resistant installation box. Durability of the installation box is a necessary prerequisite, as everything is located on the outer surface of the collecting car chassis.

Industrial PC was developed as a single-board computer operated with a modified distribution of Linux operating system. The computer allows the communication through digital inputs, RS232, RS485 and Wi-Fi.

If the on-line monitoring of the process of collection is necessary, the computer can be extended to include GPRS module for real-time data transfer. Identifier of the container under emptying operation is displayed by the computer on a built in LCD along with a simple

optical and acoustic signaling output. The system also integrates two optical sensors that inform the inbuilt computer about unloading of containers according to the position of the container lift. It is also possible to extend the system functionality by connecting the computer to the lift scales that are able to measure the weight of collected waste.

SW applications

During the container unloading process is together with the identifier also the place and time of the lifting mechanism initiation received and stored in the system. In this way it is possible to clearly and accurately document the movement of collection vehicle, the number of lifts of the lifting mechanism, the number and type of collection containers and other operating data. If necessary the system is ready to record the GPS coordinates of each container unloading process and immediate transmit the data via the GSM network. By preferences of the waste collecting companies the identifier read from the RFID tag after the unloading of the container is either sent immediately to a central database, or is temporarily stored in the memory of the on-board control system until arrival at the depot, where a mass upload of data is performed.

Data can be exported into an already used information system, for example, the billing system. In the case that no such system was currently used or the company does not want to integrate those systems, the collected data can be stored in the GBC LINE database system. This system allows us to view the records, create statistics and reports for printing. GBC LINE is also possible to provide data to other applications to consequential processing.

Economic and Environmental Benefits of the System

One of the current strategic goals of human society is to promote waste separation with increased respect to the environment and gradual decrease of disposal costs. Therefore, it is desirable to separate the waste and reduce the costs associated with its disposal. With the introduction of the system described, these savings do not relate only to the agglomerations themselves but mainly to the citizens. Through weighing of the waste during each unloading we can clearly identify how many tons and which type of waste was produced in certain district or in exact house, what percentage of it were the recyclable waste and the mixed waste. Based on these data the authorities may implement fair discount on the waste disposal fees in the areas with greater social responsibility to sorting waste, the citizens in such areas may be given financial bonuses for sorting at the end of the year or there could be other types of incentives.

The main reason for implementing above mentioned solution was to ensure high productivity while enhancing the credibility and provability of the data that are the basis for payments for the waste disposal, additional services provided to the client and for the continuous records of waste production and management. The percentage of unsorted waste produced by citizens decreased from 76% to 45% in the first six months of the new management system operation. As a result, most of bio-waste was separated from the municipal waste. Compared to the last two years there has been a decrease in municipal waste production by almost 37%. Further years of operation brought even more striking results. This data could be calculated for individual clients exactly thanks to the RFID identification. The savings achieved thanks to the automatic identification of containers were so high that the return on investment to RFID technology was done within the first year of use.

The benefits of implementation of the above mentioned system can be summarized to the following points:

- Verifiable evidence of unloading of any waste containers.
- Verifiable route of collection vehicles and their mileage.
- Application for dispatching station with overview of collection vehicles movement.
- Overview of the weight of the contents of each container unloaded in certain locations.
- Overview of the percentage and amount of waste sorted in certain locations.
- Fair pricing of waste collection fees in the areas which sort more than others.
- Savings on the administration related to unloading and log book maintenance.
- Greater confidence in the waste separation efficiency in the society and proof of its economic impact.

Vision of Future Trends – Internet of Trashed Things

Nowadays, one of the technological trends is the Internet of Things (IoT). We can imagine it as another layer of the internet in which it is not just people who communicate but also the things of daily consumption and use - your refrigerator will tell you that it is running out of food or it makes a food order right away, your favorite music starts playing after you get home and the lighting level is set to your favorite value for a given time of the day. This is possible thanks to the fact that these things are equipped with sensors and often also with other electronics able to realize mentioned logics to evaluate physical quantities in their surroundings or means of communication with other devices. For example, the information from the GPS location of your mobile phone will remotely activate the thermostats in your home right when you leave your office, to reach the right level at the time you come home. In the case

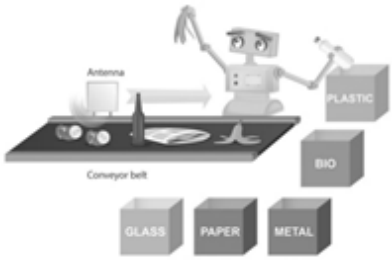

Fig. 5 RFID technology helps waste separating0

Rys. 5 Technologia znaczników RFID w segregacji odpadów

of waste containers, for example, it may be the sensor indicating the state of container capacity. The container can subscribe to the waste collection route when it is full or reaches specified level of waste. Otherwise the route could be altered to avoid that container and optimize the fuel consumption. Since the IoT has come into the consumer world a similar trend can be seen in the industrial world where it is called the Industry 4.0, which brings such procedures into the world of industry and enriches them with elements of artificial intelligence, automation and especially robotics.

The life cycle of consumer units, that by themselves or because of their packing form the grand majority of household waste, begins with the units manufacture where the RFID can be used to capture all production processes, intern logistic history, transport temperature conditions and so on. While meaningfulness, savings and efficiency of the RFID tags application onto logistics and business packaging of units (pallets and bulk packaging) has been established and proved and it is widely used, the RFID tags have not reached such penetration to the area of consumer units yet. There are exceptions, such as the clothing industry, medicines or certain types of expensive luxury goods where RFID proves the authenticity of the product using electronic pedigrees. Applicability of RFID to more products is limited by the price of RFID tags that is currently too high for many products. Although the cost trend is declining down in price, it would still disproportionately increase the price of the cheapest consumer items.

The life cycle of consumer units includes also its destruction or disposal of the packaging in which it was stored. Because the RFID tag provides identification of both content and packaging of consumer units, this information can be used for waste sorting and safe waste management. For example, the automatic waste sorter can recognize the waste with glass, paper, plastic or metal packaging using the RFID (see Figure).

If you already start to think in these terms, you can probably easily imagine the waste containers and garbage bins equipped with SMART sensomotorics that is able to sort and process waste inside the container using electricity supplied by the solar panels integrated in the surface of the container. Since drones would be used as transport units for package delivery in the future, we can also imagine a flock of drones that fly over the street back from delivery and on the basis of image analysis, they evaluate the waste on the ground. The drones would then pick the waste themselves, take it to the waste container and sort it properly. The top of this technology would then be a waste container that recognizes whether the waste type you throw in was a proper one and if not, it warns you against doing so.

Results and Discussion

Sensors on the SMART waste containers, collection vehicles and identifiers on the discarded consumer units are the source of large amount of data. This data can be transformed into information and knowledge using analytical tools. In the future, we can imagine a variety of statistical analyses describing how the waste collection was improved at the certain districts on the basis of other variables which we decided to use to do this situation better. We can assess which region is leading in the sorting of waste or which, in reverse, is lagging behind them and therefore we should launch an advertising campaign to popularize the sorting practice and do some educational efforts at those who are lagging on recycling. These efforts would include distribution of printed and electronic literature, mentions at city meetings and, in some cases, personal visits from inspectors. We can also find usage for the optimization tasks associated with determining the intervals when and where the collection vehicles should go. There are certainly areas which continuously produce more waste and areas which do not need to be attended that often.

Conclusion

In this paper we discussed the situation of the waste collection management systems in and outside of the Czech Republic. We briefly described our solution of the waste collection management system based on an RFID technology integrated into a collection car and the waste containers. For the identification of the con-

tainers contactless UHF RFID tags were used. This technology allowed us to perform the identification process without direct line of sight for quite a long distance. Therefore we proved that UHF RFID technology is suited for entirely automatic identification of the waste containers without any human operation intervention. The human factor elimination from identification process ensures high productivity and in particular high credibility of the data that are the basis for payments for the collection and transfer of waste as a client service and continuous records of waste production and management. At the end of the article we briefly presented also a few possible ideas for the future of waste management.

Acknowledgement

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Zastosowanie pakietu RFID w systemie gospodarki odpadami

Integralną częścią analizy cyklu życia (LCA) urządzenia jest jego unieszkodliwianie i gospodarka odpadami opakowaniowymi. Znacznik RFID używany jest do identyfikacji produktu i opakowania. Informacje te mogą być wykorzystane w procesie selektywnego sortowania odpadów w celu bezpiecznego gospodarowania odpadami i do optymalizacji wtórnego wykorzystania. Jednak obecnie wdrażanie znaczników RFID dla każdej jednostki jest wciąż wizją przyszłości, a technologia RFID w gospodarce odpadami stanowi wyzwanie.

Automatyczna identyfikacja i zbieranie danych w procesie zbierania odpadów komunalnych może dostarczyć użytecznych informacji. Takie informacje są ważne zarówno dla klienta, który może mieć pewność, że płaci za rzeczywiste usługi, jak również usługodawców, umożliwiając im łatwe i niezawodne świadczenie usług umownych w zakresie zbierania i przetwarzania odpadów.

W niniejszym artykule omówiono zastosowanie znaczników RFID w celu określenia czasu i miejsca pojemników z opróżnieniem odpadów komunalnych oraz zaletami systemu opartego na tej zasadzie.

Słowa kluczowe: znaczniki RFID, system gospodarki odpadami, GPS; Internet przedmiotów śmieciowych, IoTT