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RFID Application in Municipal Solid Waste Management System

Abdoli, S.

Department of Computer Science and Software Engineering, The University of Melbourne, North Melbourne, Victoria, 3051, Australia

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ABSTRACT: Processing and recovery is a key functional element in municipal solid waste management system (MSWMS). Reuse, recycle and recovery of valuable components of waste stream are given much attention in MSWMS in both developed and developing countries. The main concern of municipalities is the sound management of recyclable materials. Source separation as a best practice for management of trash and recyclable materials is known to every municipalities. Since 1980 many technologies are used in recycling industry. Many municipalities are learning the importance of new technologies in recycling industries, such as radio frequency identification (RFID). This technology has been used widely by many organizations in some industrialized countries. Radio frequency identification is a tagging system for automatic identification of recyclable components of municipal solid waste stream. This paper reveals some applications of RFID technology in Product self-management, with emphasize on municipal solid waste management as well as environmental implications of RFID. Broad usage of RFID tags on consumer products bears risks of dissipating both toxic and valuable substances, and could disrupt the established recycling processes. This causes a potential mid-or-long term risks with respect to resource management and pollution control. However, these risks could be avoided or mitigated applying precautionary principle in the early stage of development of RFID technology.

Key words: Radio frequency identification (RFID), Recycling, Municipal, Solid waste, Management

INTRODUCTION

Radio frequency identification (RFID) technology is emerging rapidly in the fields of manufacturing and logistics in many developed countries. It can be part of an inter-organizational network for improvement of efficiency of the processes in the supply chain. Rapid development of RFID technology and its implications on the field of environment have caused municipalities to pay more attention to usage of RFID for more efficient collection of trash and recyclable materials. One of the exciting aspects of RFID is to shift responsibility of product management toward the product itself. In the European countries, recycling and solid waste management policies are the driving force for exploitation of RFID in waste management (Thomas, 2003). RFID technology is becoming more vital when the reverse supply chains for the reuse, recycling and disposal of goods such as personal computers are globalizing (Williams *et al.*, 2008).

RFID is used to build up an ''internet of things''— a network that would allow companies to track goods through the global supply chain and run many applications simultaneously (Violino, 2005). According to the market research analyst IDTechEx (Das, 2005), the cumulative sales of RFID tags for the 60 years up to the beginning of 2006 reached 2.4 billion, with 600 million tags being sold in 2005 alone. In 2006, 1.3 billion tags and 500 million RFID smart labels were used in retailing, logistics, animals and farming, library services, and military equipments. RFID has become a new and exciting area of technological development, and is receiving increasing amounts of attention.

*Corresponding author E-mail:s.abdoli@pgrad.unimelb.edu.au

RFID is also an exciting area for research due to its relative novelty and exploding growth. RFID research has led to the emergence of a new academic research area that builds on existing research in a host of disciplines, such as electronic engineering, information systems, computer science, and business strategy. There has been a significant increase in the number of papers on RFID in research journals.

MATERIALS & METHODS

A common RFID system usually consists of tags, readers, application software, computing hardware and middleware. The low frequency RFID which is used for solid waste management consists of reader, antenna and passive low frequency tags. In this paper the main components of RFID system applicable in municipal solid waste management system (MSWMS) are discussed. RFID tag in principle is a microprocessor chip, consists of an integrated circuit with memory. Each tag has its own identity. These tags are mounted on the container or waste bins.

The identity of each tag is broadcasted to a reader with the same frequency and the same tag protocol. Antenna acts as a communication channel between the tag and the reader. The antenna can transmit data from its sideways and front. Design and sitting of the antenna are very crucial for coverage area and precision. To energize the tag, the antenna gets energy from the reader's signal, the antenna then sends the receiving data from the reader. The reader is a piece of equipment that reads the data and prints the data to the compatible tags.

Exact location of the tags is identified through communication between tag and reader. These data can be transferred to a server through a computer network, by which, the movement of the item can be tracked and traced. Therefore it is necessary that the frequency of tag and reader be the same and complies with specified regulation. At present, four types of readers are available: handy, vehicle-mount, post –mount and hybrid. The first three types can read either passive or active tags, while the last one is able to read both passive and active tags, through switching mechanism.

RESULTS & DISCUSSION

RFID is a fast growing technology in a wide variety of fields. RFID has successfully applied in supply chain management, manufacturing and logistics, but its range of applications extends far beyond these areas. RFID has many applications in the field of environment (Thomas, 2009). Perhaps one of the best ways to manage the source separation program efficiently is the usage of RFID technology. This technology plays an important role in MSW collection operations. RFID is getting more attention in different industries. Today many companies in industrialized countries have applied this technology in real- world environment. RFID is an emerging tecnology, and it has a wide variety of applications in many fields. Some of them are listed below (Ngai *et al.*, 2006).

- Animal detection.
- Aviation.
- Building management.
- Construction.
- Enterprise feedback control.
- Fabric and clothing.
- Food safety warranties.
- Health.
- Library services.
- Logistics and supply chain management.
- Mining.
- Municipal solid waste management.
- Museums.
- Retailing.

RFID tags could provide an individualized environmental footprint for retail products that would differ based on where the product is sold. As a produst travels from the factory to the distribution center and store, it will pass a range of RFID sensors. A database could collect the transportation history of product as well as information on the transportation mode. The automated environmental lifecycle assessment software could calculate the associated environmental impact. This individualized record could be particularly useful for fruits, vegetables, baked goods, meats, and other food products that can have widely varying impacts by season and by location. With tracking of individual animals with RFID tags, environmental and consumer information can draw on the complete supply chain,

back to the specific animal.RFID technology has been very helpful in collection and recycling of solid wastes in many areas. The role of RFID system in these two functional elements of MSWMS are discussed below:

One of the results of smart labling is to shift responsiblity for product management toward the product itself, and hence make the recycling and reuse easier. Product recycling and reuse are difficult and complex task. There are many obstacles for product reuse and recyling:

1. Products are distributed all over the city, therefore the sources of consumed products and recyclable materials spread all over the city and dispersed among the consumers. Concequently finding and collecting the consumed products for recycling or reuse is not an easy task.
2. Generation of municipal waste and recyclables take place in every home, apartment building, and commercial and industrial facility; as well as in the streets and parks. Therefor the pattern of waste are diffused and the logistics of collection become more complex (Ghiasinejad and Abduli, 2006).
3. Each product has many diferent models with diferent end-of-life procedures.

Recycling of the spent goods could be easier and cheaper by establishing a product self managment system by considering information tecnology at product deisign. This can make the products to manage their end-of-life automatically. Product self managment consists of a wide range of activites, such as end-of-life managment, energy consumption and managmence during the life of the prouducts. In this concept, products must contain the information's required for recycle, repair or sell. In advanced level, the consumed products put in the trash may cell themselves to scrap dealers or on the internet.Waste collection agencies or even authorized companies, businesses or consumer could automatically search the content of the on-site storage containers for special items and schedule collection service accordingly.When this happens, there will be tremendous amounts of source reduction on municipal waste steam, and per maps the waste management activity becomes economically for both municipalities and citizens.

Product self management could become wide spread reality by technological improvement in the area of internet and labeling.In connectional labeling systems products are identified by reading scanning label or typing it into a computer.There are several technologies to identify products automatically and without human intervention. RFID tags have shown a high potential for product self-management and it is anticipator to replace the ordinary barcodes (Auti-ID Center, 2003).In European countries waste recycling is the main area for early application of RFID tags.

Majority of the European household are RFID enabled garbage collection service are an easy and automatic means for weighing on-site storage bins during the curbside collection service. Waste collection trucks are outfitted with a scale to weigh the waste bin, and the household is identified through an RFID tag on thewaste bin. An RFID antenna and reader on the truck reads the tag on the waste contaner when it is placed on the truck's scale. In Germany, 20% of garbage collection is managed with such RFID systems (Minec. Case Stories:Botek, 2003).

In the United States of America such a weight-based "pay as you throw" system for household waste collection is not existed. In Europe, this system has caused a significant increase in household recycling rates (SERA, 2002). The waste weighing system may be implemented by RFID tags. The general ability of a computer connected with waste truck that can receive the information of each bin is the essence of this novel technology.This waste collection service pave the way for product self-management system.

RFID-enabled waste weighing system could provide the ability to measure mass of the waste constituents, and identify each waste component with RFID tags on it. RFID tags on each waste component are read simultaneously with the tag on the bin by collection truck.Usage of this system makes possible the rebates for recycling of products. At present there is a significant interest for waste recycling in European countries. It is anticipated that use of RFID tags on recyclable tags become mandatory to facilitate waste recycling programs, or all the products must have RFID tags to make rebates of them easier. Big

step toward product self-management is to have RFID and antenna and reader on waste bins rather than the truck .as soon as a recyclable material is pot on the bin it can be identify and relay the data through a central system to a scrap dealers, and other related parties such as internet-based sales services. Thus the recyclables could be picked out from the waste bin prior to general pick up.

Many municipal solid waste collection agencies in Europe use 135KHZ RFID tags in their residential on-site waste containers. Each container in identified by the truck equipped with RFID reader and picks up. The waste generator then is charged according, the contract. This collection system works on the bases of pay-as-you-throw principle. For those cities which do not fallow this principle, RFID is use for efficiency improvement of collection services.In 2001, there were %2.8 increases in receipt from being able to find and assess previously un-assessed bines Among the German municipal Waste Management Company using RFID-based systems. For municipalities following pay-as-you-throw principle, it is reported that the amount of non recycle waste disposal are decreased by 35%, and there was a reduction of 17% in the waste generation (VKS, 2001). This findings fall in the range of the results in USA companies following pay-as-you-throw principle with 25-35% reduction of municipal solid waste disposal (USEPA, 2005) to increase recycling rates, another alternative to this system are applied by a US company)Recycle Bank(. When the recycled materials are picked up by the collection truck, it weights them, and sends the customers coupons based on the amounts of waste recycled.

RFID transponders can increase recycling rates of different waste components such as batteries, electronic waste, hazardous materials and valuable recyclables. Sorting of different types of batteries could be cheaper and easier using RFID tags on batteries. Tags on electronic appliances could show the method of dismantling the products. The contents and kind of treatment and disposal of hazardous materials could be identified by RFID tags attached to them. Reselling the consumer products could be much easier with RFID tags.

RFID is an extension of the UPC trend which is used in one-way supply chains that links the physical world of commerce to the world of information. RFID codes stay on the products, even after the products are being thrown away. This product code make possible, to establish different kinds of recycling incentives or disincentives systems in municipal solid waste management activities.By recording the exact time of putting the items in a container, it is possible to design a program for reward or punish improper disposal. Even though recycling incentives such as deposits on bottles are known practice in municipal solid waste management, but usage of RFID technology for product mediated approach reduces costs and supports innovation. RFID could provide small and high incentives for low and high value items respectively. Variety of targeted rebate programs for deferent items could electronically be managed in a single curbside recycling collection service, for variety of consumers, products and geographical regions.

Although, RFID system as well as UPC barcode are capable to implement product codes successfully, but RFID has an advantage over UPC barcode; because different RFID tags can be read at the same time and through the other products. For products such as computers that may be upgraded internally, RFID has an advantage; the tags inside the case and tags of the new parts can be read through the computer case. This aspect of RFID tags is very crucial in waste recycling activities. On the other hand for conventional applications such as cases in which the code are to be read in the store or at a drop-off center, UPC barcode is chipper and easier to be used; because the items must be read one by one and the UPC barcode readers are already available. Anyway cost is important issues that must be consider applying any innovative technology. Recycling is not very beneficiary and can not justify the cost of item-level RFID tags (Thomas, 2008). But if RFID tags al to be put on the products and already excited for other proposes RFID-assisted recycling programs could provide tangible secondary profit.

There are a number of possible ways to manage the first step of the reverse supply chain:

consumers could have to sort their own recyclables into different bins, consumers could get a rebate for returning packaging to a recycling center, consumers could have to call for pickup of special items for recycling like refrigerators or furniture. Or items could be mixed in the recycling bin and sorted later, at a materials recovery facility. Different choices could be made for different geographic regions, for different products, and for different customers, but all could use the same RFID code.RFID have many different applications in MSW recycling programms, some of these applications are:

A. RFID for Electronics Refurbishment
B. Item-level curbsid recycling
C. Smart Trash Cans
D. In-store recyclables collection
E. RFID at Materials Recovery Facilities

In developed countries the current collections services and payment models is manual, and is the responsiblity of the truck driver. Usage of RFID technology on waste colletion services, not only increases the waste management efficiency thorugh automation, But also enhance the environmental responsibility and concerns of the citizens. These are the main drive force causing many municiplities taking a closer look to improve their MSWMS using RFID technology. Fig. 1. demonsrate a common curbside collection practice (wyatt, 2008).

Human error in manual operations is inevitable and may interfere with the main responsibility of the truck driver which is more risky. To overcome these short coming, The low frequency RFID is a solution. Application of this technology in MSWMS, not only improves the efficiency of the system, but increases relibility and public acceptance of the consumer billing procesure.The pay- as- you- throw principle with RFID, inter connect recycling to incentive program in which, generators pay according to the amount of their waste and recycle which is differen from the conventional definition of PAYT. Fig. 2. demonstrates a RFID -Enabled waste collection process (Wyatt, 2008).

Like any new technology, Rapid emerge of RFID in MSWMS may cause some negative impact on environment, precautionary principle, dictate to consider these impact carefully, and analyze the final disposal of recyclables, packaging

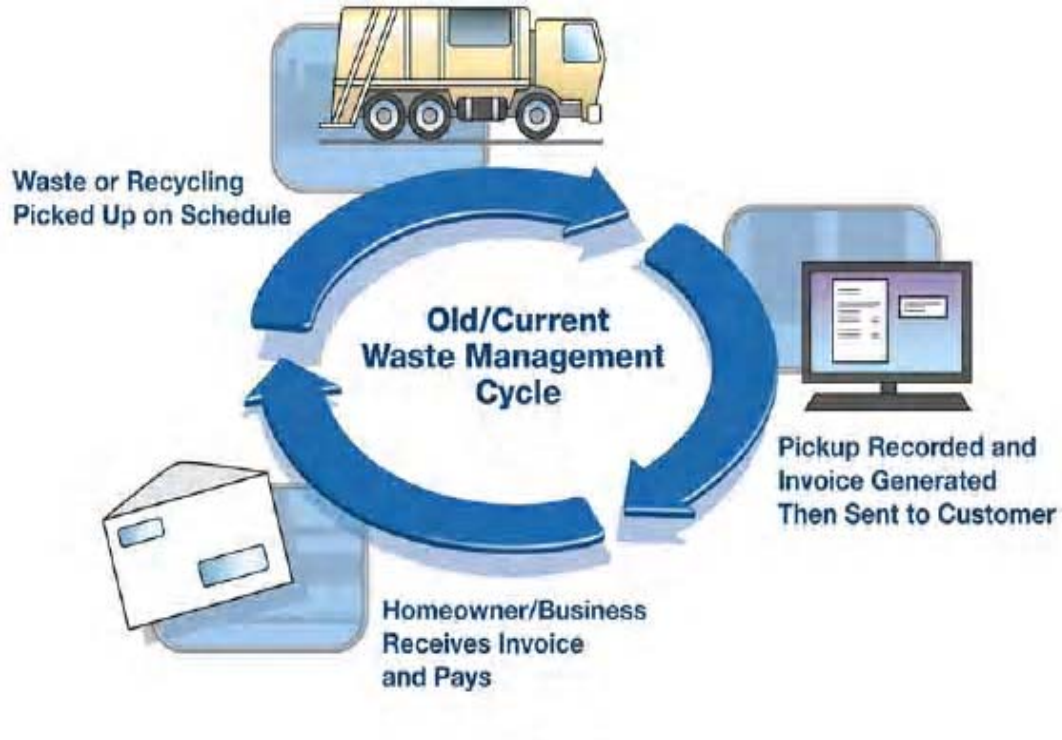

Fig. 1. Illustrates Waste Management without RFID Technology

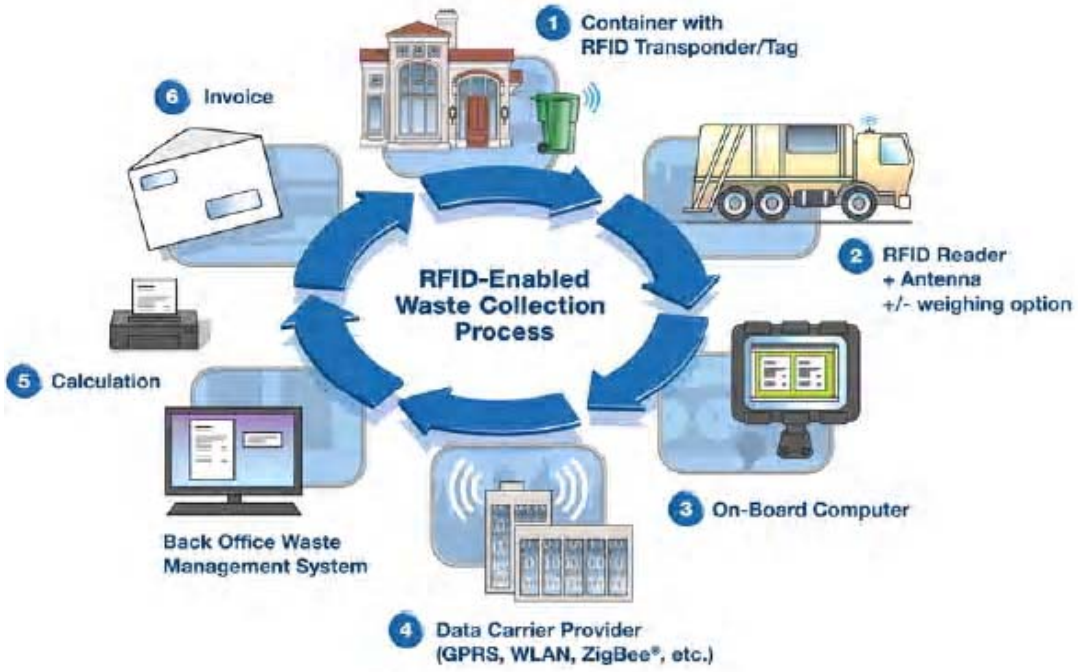

Fig. 2. RFID and Technology Enabled Waste Management Cycle (Automation of the waste collection process)

materials and other consumed products. Wide spread use of RFID components especially in recycling programs may cause some risk of dissipating both toxic and valuable substances, and of disrupting established recycling processes.

The rapid growth of RFID applications in different fields could accumulate the spent tags antenna and readers on municipal waste streams. It is anticipated that the consumption of RFID tags will reach 2 trillion tags each year. Thus the huge amounts of copper, silver compounds, silicon, adhesives, plastics contained in these tags end up in municipal solid waste globally. This is the main concern in the recycling of plastic, paper, glass, steel and aluminium (British Glass, 2005).The vast usage of RFID technlogy bears some risk of dissipating both toxic and valuable substances to municipal waste, and may cause disruption of the existing, recycling process.

The potential environmental impacts of wide spread of RFID technology has to be analyzed in disposal and recycling of packaging materials containing the RFID tags from perspective of the precautionary principle (Wager *et al.*, 2005). It is obvious that there are some risks associated with the implication of this novel information and communication technology in recycling industries and municipal solid waste processing (Hilty *et al.*, 2005; Oertel *et al.*, 2005). Application of the precautionary principle at the early stage of development of any novel technology such as RFID, provides a platform to foresee and mitigate the risk of this development and at the same time promote the positive aspects. Hence the potential irreversible damage under the uncertainty conditions could be avoided (Renn *et al.*, 2003; IDA Vorsorgeprinzip, 2003).

One of the obstacles for recycling is the separation of embedded components of microelectronics from recyclable materials. These electronics usually contain hazardous and valuable materials and they have to be separated from the waste streams and treated. This can cause some long-term risks regarding resource management.

Wide spread application of RFID tags typically containing hazardous materials on consumer products may cause the potential risks in terms of the irreversibility criterion. These tags are categorized as small electronic components. These components are not large enough to separate them relatively easy from non-electronic waste streams. Today, microelectronic components such as RFID tags are increasingly embedded in commonly used

consumer goods. Separation of these small components for special treatment is not economically feasible. Microelectronic components attached or embedded to packaging materials, may cause the potential mid-or-long term risks with respect to resource management, pollution control or recycling processes. In this context among the recyclable materials, the impacts on recycling of aluminum, paper, glass, PET and tin plates are more noticeable. Two potential impacts can be expected concerning the wide spread usage of RFID technology (Wager *et al.*, 2005):

- Dissipation of toxic and/or valuable substances
- Potential disruption of established recycling systems.

The potential impacts of the wide spread application of RFID technology in MSWMS is dissipation of toxic and/or valuable substances in consumer goods and recyclable materials. This in turn could disrupt the established recycling systems.

CONCLUSION

The biggest environmental challenge facing the MSWMS is the implementation of 3R stratgy. Waste processing and recycling have been the world wide key technologies during the last two decades. In promoting the performance and efficiency of MSWMS, in developed countries, the main concern of municipalities is the sound management of recyclabes (Josh wyatt, 2008).In these countries many municipalities are learning the importance of new technologies in recycling, industries, such as radio frequency identification (RFID); This technology has been used widely by many organizations, in some industrialized countries (Ngai *et al.*, 2008).In this paper applications of RFID technology in MSWMS, especially in advanced recycling are discussed.RFID technology is emerging very rapidly in recycling industry, and it will penetrate faster in the near future. This technology like any other novel technology has its environmental consequences, which must be addressed. In this paper the implication of recycling waste containing RFID tags are analyzed with respect to precautionary measures.

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