Using Transponder Technology to Support the End-of-Life Phase in Product Life Cycle Management

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Abstract

The first part of the paper describes opportunities of the RFID technology and its possible role in life cycle management. As an example for the opportunities of RFID technology in the EOL phase, the second part of the paper discusses the recycling of bumpers (combined with a transponder) coming from dismantled cars or repair shops. This example bases on existing technologies and possibilities for the recycling of bumpers combined with RFID technology. The third part discusses the realisation of innovative decision support tools, which can be adopted for various issues within enterprise networks and the process chains in the field waste and recycling management.

Keywords

RFID, recycling, decision support.

1 Introduction

With the transponder or Radio Frequency Identification (RFID) technology exists a technology, which is capable to trace products along the life cycle from the design phase until the final recycling or disposal. In the beginning of a product life the information availability is of high density in comparison to the mid of life and end of life, which is currently of low density regarding the availability of information belonging to the product. This causes high costs for repairing or recycling products, which is one of reasons for giving products to incineration or disposal.

If the potential improvement of processes in the product life cycle via higher data availability is systematically investigated, this could lead to higher recycling rates, which are the basis for more closed material loops.

2 RFID Technology and Fields of Application

The transponder technology is an automated identification technology, which is based on data exchange via electro-magnetic fields. The core of any RFID system is the 'Tag' or 'Transponder', which can be attached to or embedded within objects. A RFID reader sends out a radio frequency wave to the 'Tag' and the 'Tag' broadcasts back its stored data to the reader. The system works basically with two separate antennas, one on the 'Tag' and the other on the reader. The data collected from the 'Tag' can either be sent directly to a host computer (e. g. by Wireless Local Area Network – W-LAN) through standard interfaces, or it can be stored in a portable reader and later uploaded to the computer for data processing. The RFID tag system works just as effectively in environments with excessive dirt, dust, moisture and poor visibility, also to be found in the recycling industry [following RF-ID.com 2003].

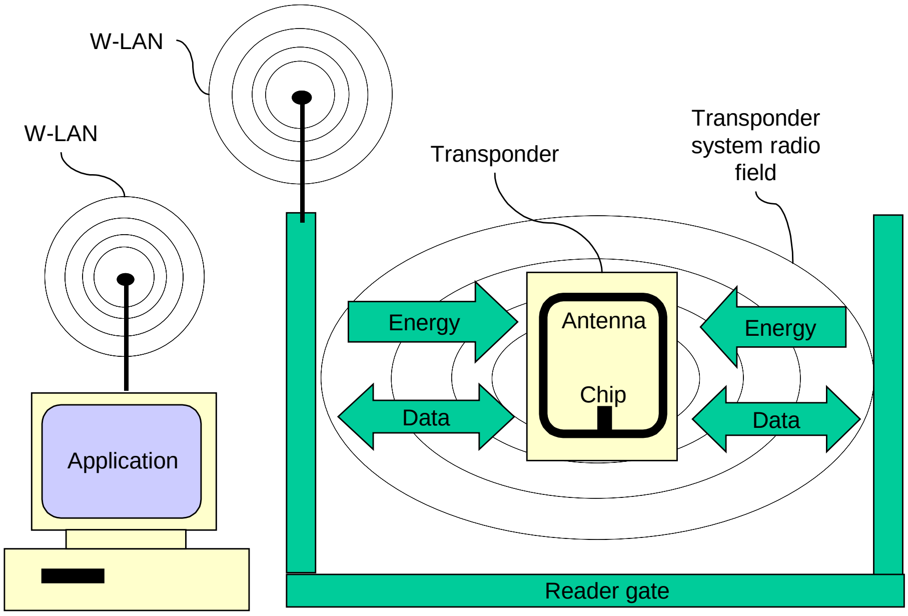

Figure 1: RFID system combined with W-LAN

Typical application fields are e. g. toll collections, baggage handling, animal tracking or identification of containers. In comparison to other traditional identification systems (e. g. bar code systems) transponder systems are capable to store data during the whole life cycle directly on the embedded chip. The data storage capacity is from 1 bite up to more than 64 kbite. This means that the transponder has also a function of an external, mobile database.

Furthermore additional functionalities, like temperature or pressure measurement, are possible.

3 RFID Technology and Product Life Cycle Management

For improving the product life cycle management the features of the RFID technology will have a positive influence on closed recycling loops. By establishing a link between the customer and the producer or recycler of a product, new services can be implemented and existing ones optimised. The following paragraph will distinguish between 3 different mayor phases in the in life cycle of a product:

Beginning of Life (BOL) - Product design (process) improvement: RFID technology appears as ideal solution to increase not only product data quantity but also quality and consistence available for the later usage in a (re-) design process. Smart products are in the position to log their individual history such as usage conditions, failure, and maintenance or service events. Product information based on the aggregated individual product MOL data is extremely valuable for the assessment or improvement of the product design process.

Roles in this scenario are typically product designer or engineers, service or maintenance employees and the customer respective owner of the product. In opposite to the former processes of information gathering by market research and feedback collection from distributor or service agencies, this scenario provides more detailed information on product usage but also requires the active integration of the product owner to the overall processes.

Mid of Life (MOL) – Maintenance / Service processes: Process scenarios in this phase mainly covering the aspects of one single product, or an instance of a product. By attaching unique tags to a product, it is possible to establish a linkage between the customer, the producer and the product, thus allowing for customer oriented updates, service, maintenance, etc. Such products, that are prepared to enable additional business via extra services, are also called smart products.

Smart products are able to provide information on how to use or how to maintain the product but they might be also providing information concerning the history its usage which is for example of particular interest for individual maintenance activities or complaints in case of product failures. Roles in this scenario are typically maintenance or service agency employees and product owners.

End of Life (EOL) – Recycling and disposal: The availability of information about the product in this stage is on a low level, this means that waste manager have usually no opportunity to recycle the product or parts of the products on a better level than incineration or disposal.

In addition to the information for the BOL and MOL phases, which is more directed on the user behaviour and general changes during the product using phase, the recycler needs information at a first level for rapid sorting processes (e. g. directed on brands and / or product types) and more detailed information for dismantling and component sorting processes e. g. by material, quality and functionality.

At a glance the described scenarios can be considered as simple information management tasks not highly sophisticated from the technological perspective. More than this some of this information are still managed e. g. by Customer Relationship Management (CRM) systems and it seems that the integration of RFID technology simply shifts the emphasis of these scenarios from a more organisational to a more technical task.

Costs and Risks

In addition to the described benefits also investment costs and risks have to be taken into account (like loss of privacy, loss of information to a competitor or loss of information, which is e. g. important for the function of a RFID optimised supply chain).

The following table gives an overview on the estimated benefits, investment costs and risks for the involved parties arising with the implementation of RFID technology to the described process scenarios. The table displays the average opinion of the authors and is related on the example of recycling of car bumpers (see next chapter).

	Producer	**Owner**	**Service**	**Recycler**
Benefits	High	Medium	High	High
Costs	High	-	Medium	Medium
Risks	Medium	Medium	Low	Low

Table 1: Benefits and risks of RFID technology combined with car bumpers

These stakeholder-oriented risks have to be solved by sufficient security systems, based on encryption, back up storage systems and parted identification systems (e. g. RFID chip combined with barcodes).

4 Recycling of Car Bumpers with RFID Technology

For a better understanding of the opportunities of the RFID technology in the product life cycle management, this chapter describes a possible recycling scenario for car bumpers. Parts of this scenario are based on a running research project dealing with the improvement of logistic processes in the EOL area with the transponder technology (OPAK - Optimised PAcKing logistics in the life cycle economy, funded by the German Federal Ministry of Education and Research).

Figure 2 describes possible application fields for the RFID technology in the life cycle of car bumpers with an attached or embedded tag from the producer side: After use and dismantling the single bumper or bumper fraction goes to the collection point (e. g. an open container) by passing a reader gate (see Figure 1). This reader gate reads all data from the single bumper tag and writes data on the tag (see Table 2).

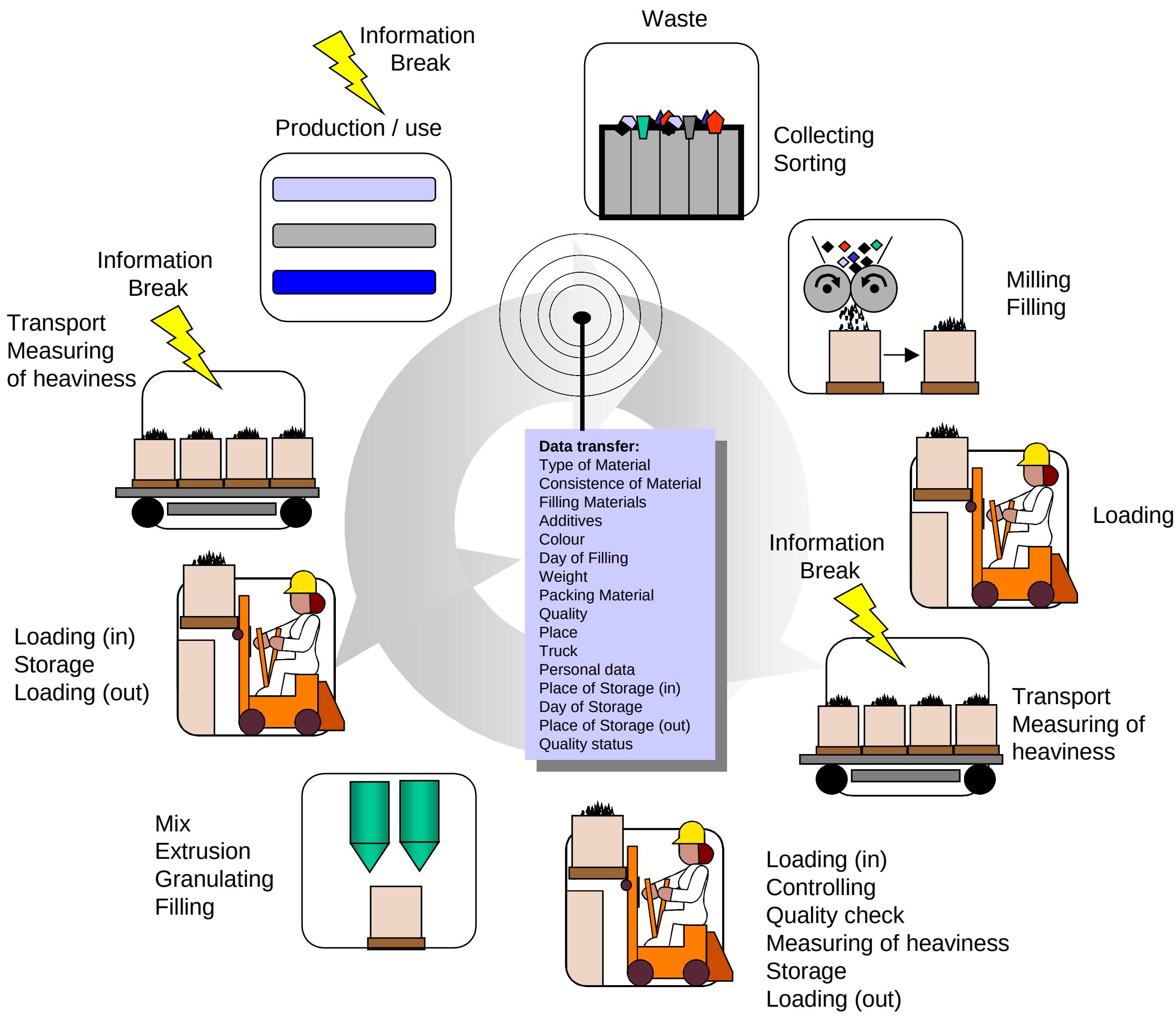

Figure 2: Use of RFID technology in the life cycle of bumpers

The milling starts after a sufficient amount of bumpers is available. Before the milling, a manual or automated sorting system sorts the bumpers for recycling from the container fractions. After milling and filling the material goes via a truck to another recycling facility. There the material goes into a storage system. On customer demand this facility produces new plastic granulate, which is basis for new plastic products.

The different process steps have different requirements of data exchange. Table 2 describes examples for an information exchange between the transponder and the collecting / sorting production, transport, loading and storing systems.

The transponder technology enables in this example the data acquisition of the collected material types and -mix at the collecting point, i. e. at the place of waste collecting, in temporary storage facilities systems or in storage systems of external logistic services.

Advantages are the ubiquitous availability of data about the material during the whole recycling process. Breaks in the information chain (cf. Figure 2) are buffered via the transponder chips. The fast information exchange by passing reading systems is more efficient than the manual scanning of barcodes.

As an additional functionally it is possible to control the temperature of the packed material (granulated plastic is self inflammable).

Process step	Data exchange (examples)
Collecting / Sorting	Bumper transponder to production system: Additives, brand, colour, consistence of material, bumper identification number (external), type of material, weight Recycler production system to bumper transponder: Day of storage, personal data, place of storage (in), bumper identification number (internal), quality
Production	Production system to packing transponder: Additives, consistence of material, day of filling, personal data, place of filling, packing unit identification number, status, type of material, weight, machine number Packing transponder to production system: Packing identification number, temperature
Transport	Packing transponder to truck: Packing unit identification number, material, place of storage on truck, weight, temperature Truck to packing transponder Personal data, truck number plate
Loading	Packing transponder to fork lift: Packing unit identification number, material, place of storage on truck, weight Fork lift to packing transponder: Day and time of loading, fork lift identification number, personal data
Storing	Packing transponder to storage system: All collected data on the transponder (e. g. additives, consistence of material, material, packing material, personal data, packing unit identification number, temperature, weight) Storage system to packing transponder: Storage place, date and time, quality status

Table 2: Date exchange during the recycling process of bumpers (examples)

5 Real Time Decision Support

The ubiquitous availability of information accompanying the material flow can be further used in order to realise innovative decision support tools, which can be adopted for various issues within enterprise networks and the process chains in the field waste and recycling management.

Tools on top of data acquisition solutions as mentioned above can conduct further processing of the data coming along with individual entities (like bumpers) or batches. During this process data becomes information, which can be used to make better decisions on the operational, tactical and even strategic level. Examples for potential improvements on each of these levels are as follows:

Operational level

- Reaction on interference during the collection process (e. g. due to road construction) of waste or recycling material
- Reaction on unavailability of vendor parts or material in production and recycling

- Allocation for required resources for inbound and outbound flow of material / products for warehousing (loading unloading, packing, unpacking etc.)
- Control and better utilisation of transportation networks, as well as production and warehousing resources because of better information and forecasts based on real time data

Tactical level

- Clustering of areas, route planning for collection of recycling material or waste considering seasonal variability
- Production or recycling planning based on reliable information and forecasts for demand and availability
- Specification and adaptation of suitable warehousing policies (e. g. for reordering or delivery)
- Short-term adaptations of existing (recycling) networks as a result of a breakdown of a partner (e.g. selection of a new supplier)

Strategic level

- Composition and decomposition and of recycling networks (design and global optimisation)
- Long-term decisions as the location of new facilities for production, warehousing etc.
- Assessment of new technologies systems for collection, production, transport, warehousing, loading, unloading etc.

Thus real-time information concerning the various decision problems along the composition, operation and decomposition recycling networks or process chains offers huge optimisation potentials. In addition real-time information allows better forecasts and estimations regarding uncertainties and variability, which are inherent everywhere in production or recycling. In combination with tools following a holistic approach decisions and solutions can be developed which fulfils all requirements regarding efficiency, robustness and sustainability at the same time.

Today there are quite a number of approaches available in order to support the planning, control and optimisation problems related to the operation of production or recycling networks. The range covers pure mathematical methods (systems of equations), methods from Operations Research (mathematical programming), Soft Computing (evolutionary algorithms, neural networks, fuzzy methods), System Dynamics, Benchmarking or Simulation. While thinking about suitable approach for the realisation of a decision support system all of these approaches come along with specific disadvantages. Most of them are caused by the complexity of the underlying system. In this context it is questionable whether mathematical models, Operations Research or system dynamics can build adequate representations of reality. Although Soft Computing can solve even NP (Non-deterministic Polynomial-time) -hard problems and therefore fulfils the requirements regarding complexity it must be considered as a black box as the way to come to the solution, which was delivered, cannot be comprehended by the user. Another approach, which is widely used in practice, is Benchmarking. But this method requires reference cases (which are not necessarily available) in order to allow estimations about the quality of a certain decision or system configuration. Furthermore all of the methods mentioned so far do not support a holistic view for the decision support as they are either focussed one certain aspects of networks or the underlying processes.

In contrast to the other methods simulation (nearly) don't have any limitations regarding the complexity and supports a holistic view on the system to be considered. In addition simulation allows the integration of variability and uncertainty, which are always inherent in existing production and recycling systems. Thus it appears as a good candidate for an innovative decision support system. Unfortunately there are also disadvantages coming along with simulation. First of all each simulation study requires a model of the reality which will be executed within the simulator in order to get insights into the dynamics of the model which allows to draw conclusions on the behaviour of the real system. Usually the modelling process requires significant effort in terms of time and money. Therefore the application of simulation for complex but short-term scenarios is difficult due to the time, which is required for model building.

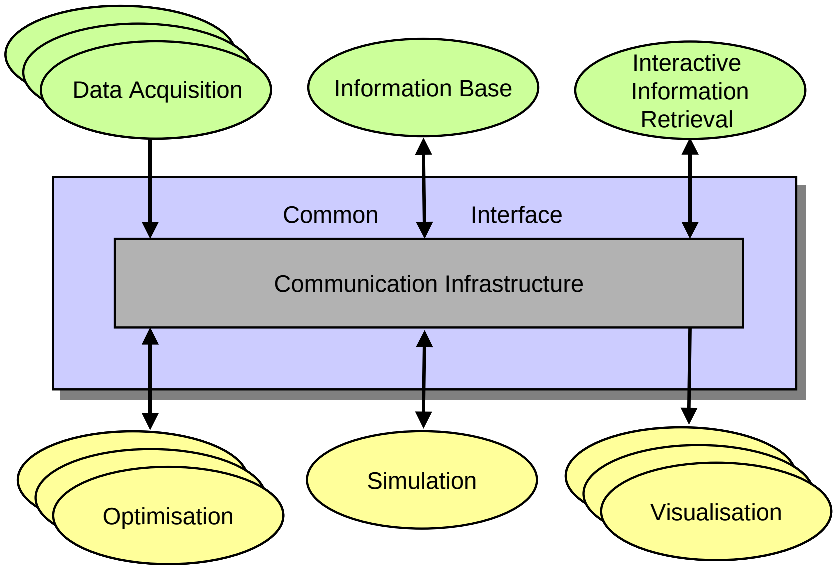

Figure 3: Architecture of a simulation-based decision support tool

Another problem covers the development of optimal or at least good solutions for a given decision problem. Due to its characteristic an environment for the emulation of systems simulation cannot propose such solutions on it's own. In fact they are developed by conducting various experiments with slightly different parameter sets in order get insights regarding the sensitivity of certain parameters concerning the overall model behaviour. Afterwards the model can be adapted considering this knowledge. However in order to find a good solution some expertise and experience in modelling and analysis of simulation data is required which domain experts as decision makers and thus the users of a decision support tool usually do not have.

However the obstacles depicted so far can be overcome with the availability of real-time information whereas the modelling effort can significantly decrease by utilising the available information in an (semi-) automatic way. Such an integrated simulation environment can be further interconnected with an optimisation module (whereas the feasibility of such an approach was already realised within the EU-funded project ONE – Optimisation methods for Networked Enterprises (Project No. GRD1-2000-25710), which in turn can support domain experts in order to identify good system configurations and make the right decisions. Figure 3 shows the architecture of such a simulation-based decision support tool.

The tool comprises several functional components addressing the acquisition of data, which are delivered by external entities (e. g. transponders while passing reader gates). After data processing the resulting information is stored within a global information base. This component provides all of the information, which is required by the other components and can be interactively accessed by the component for information retrieval. Further modules are the integrated simulator, which allows the execution of models by integrating real time information delivered from the information base. The optimisation of specific models or scenarios is furthermore supported by the communication with optimisation components whereas as different versions can be integrated into the environment each of which addressing different objectives. Finally different components for animation and visualisation allow the representation of dynamic aspects related to the underlying system or functional modules as the simulator. All of these different components are integrated by using the same communication infrastructure which is accessed by a common interface whereas the approach depicted here follows the architecture proposed by the High Level Architecture (HLA) which was developed by the American Department of Defence for distributed simulation (Originally the idea for the HLA was derived based from the problem of reutilisation of existing simulation environment in order to save development time and costs).

At the end such enhanced environments will support the decision maker in order to identify system configuration or concepts covering the whole life-cycle of products which are flexible, efficient, robust and sustainable at the same time by using an holistic approach while considering system inherent variability and uncertainties at the same time. Further application fields of the solution proposed here covers training and education of decision makers based on a “virtual reality” which can be provided by the tool.

6 Conclusion and Outlook

It’s obvious that the use of transponder technology in the whole product life cycle becomes a more important role. Traditional systems, like the barcode systems, will still exist especially in domains where the product price is on a relatively low level. Another possibility is e. g. the combination of both systems, barcode and transponder systems. This offers a high flexibility between both systems, which are depended on appropriate reader technology and safety information flows.

If the storage capacity of transponder chips is higher than 100 kB it will be possible to store complete documents (e. g. data sheets) or language based information on the chip. Additionally a data collection during the whole life cycle of the product will ease the information generation of the impact from the product on the environment and human being. This will be important for strategic stakeholder decisions and offers new business models (e. g. payment of the product use and not product ownership).

In future product embedded data storage systems might transform today’s centralised approaches in data storage to more independent data storage systems. In consequence this leads to new concepts of product ownership, where the owner not only owns the product but also related information gathered during the various stages of the life cycle.

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