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TRASER—IDENTITY-BASED TRACKING AND WEB-SERVICES FOR SMES

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ABSTRACT

Recent trends in industrial production are marked by rapid changes in structures of collaboration or competition, as well as the spreading of customized production and more intricate customer demands regarding quality and visibility of delivery processes. All this calls for efficient means of tracking and tracing beyond company borders—a technological step which is, in principle, available, yet, it is *de facto* restricted to isolated proprietary solutions excluding countless small and medium-sized enterprises from their application. The EU-funded project TraSer (Identity-Based Tracking and Web-Services for SMEs) was started with the goal of overcoming these obstacles by providing a free, open-source tracking and tracing solution platform which would allow SMEs to set up and maintain tracking and tracing services across company borders requiring low costs of initial investment and operation. The paper presents main goals and envisaged results of the project.

KEYWORDS

Tracking, Tracing, Production networks, Open-source platform

1. INTRODUCTION

Today's industrial production is marked by two trends which both necessitate efficient tracking and tracing of items or item-related data, often across company borders as well (Gunasekaran et al., 2004).

One phenomenon which is currently observed to spread is the formation of heterogeneous conglomerates—such as production networks (Linden, 1998)—where it is not uncommon that several participating companies team up only for the procurement of one product, and may act as competitors in other cases. In this case, efficient sharing of product and manufacturing data is necessary during collaboration, however, this should not imply full disclosure of the company's traffic, especially in view of potential competition in the future (Monostori *et al.*, 2006).

Also, the flexibility of customized production and advanced customer services are, more and more often, a key to competitiveness in a given field. The spreading of customization and decreasing product development times increase the risk of a faulty construction, as do varying suppliers of compatible parts or sub-assemblies potentially introduce quality risks. Therefore, a proper background for efficient quality feedback is required, including focused recall campaigns and easier identification of possible problem sources. In addition, customers will more and more often demand better visibility of manufacturing and delivery processes of the product ordered—in production networks and supply chains, all this would, necessarily, transcend company borders.

These challenges can be met by keeping track of items or data of interest, i.e., with the introduction of tracking and tracing services. Focusing on this subject, the paper is structured as follows. First, definition and typical phenomena of tracking and tracing are presented, including a state-of-the-art overview on technological and financial aspects of installation and operation. Hereafter, the TraSer project is presented in detail, such as motivation, objectives, envisaged outputs and pilot applications planned to be employed with industrial participants of the project.

2. TRACKING AND TRACING—DEFINITION AND STATE OF THE ART

2.1. DEFINITION OF TERMS AND PROBLEM STATEMENT

As already addressed in the introduction, today's production and delivery processes demand a higher degree of exact *observability* to ensure the competitiveness of the companies involved. This applies likewise to rather simple *supply chains* consisting of a large manufacturer (such as a specialized multi-national company) and its suppliers and logistics service providers, or less hierarchic but all the more changing *production networks*, as well as general *value chains*, such as companies working together on a single project, e.g., the construction of a larger building. Two important activities can form the backbone of an architecture which grants the required observability: *tracking* and *tracing*.

Tracking is the term referring to the act of observing, in most cases, the spatial motion of an entity. This may be implemented in the form of *checkpoint and timestamp pairs* (i.e., the presence at discrete, pre-defined points or stages is checked). Also, *spatial coordinates* (GPS data, length of path travelled etc.) may be used, in case the poor resolution of discrete points does not suffice. Tracking is mainly used for providing information about the advance of a given shipment (e.g., to meet correction measures in case of lagging delivery), or it might provide up-to-date information about the status of an individual alone, while aggregated tracking data may be used for optimizing future logistics operations and facilitating more exact traffic forecasts.

Tracing, on the other hand, is less concerned about the changes of the item alone. Instead, it focuses on changing *relations with the production environment*, including other components the given entity may enter a relation with. Cases like this occur in the assembly of a composite product from sub-components or the mixing of materials (e.g., food and chemicals). Tracking data gathered over a manufacturing process result in a so-called *gozinto graph*, expressing assembly relations of the form "part A goes into part B", hence the name *gozinto* (van Dorp, 2003; Jansen-Vullers *et al.*, 2003). The literature distinguishes between *forward tracing* specifying which product(s) a given component is *built into* (see Fig. 1), and *backward tracing* reporting which components a given product is *built of* (see Fig. 2). The most straightforward use of tracing is quality control, ranging from directed product recall campaigns to the improvement of manufacturing technology or work processes relying on aggregated data. In addition, aggregated tracing statistics may be used for layout or process optimization in manufacturing, as well as delivering more exact forecasts.

Tracking and tracing have been already applied in the industry for a longer period, however, not necessarily on the level of items, as especially in mass production, most of product-related administration still remains within the borders of *account-based material management* (i.e., keeping track of the amount of material present at a given location or "account"), as opposed to more elaborate views focusing on *items or smaller batches acting as individuals* during several stages of the production or delivery process.

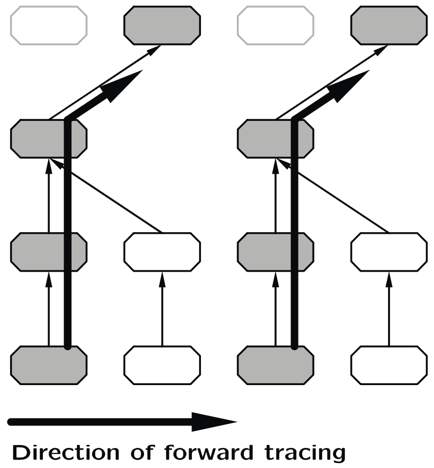

Figure 1 – Forward tracing in a *gozinto graph* of individual items

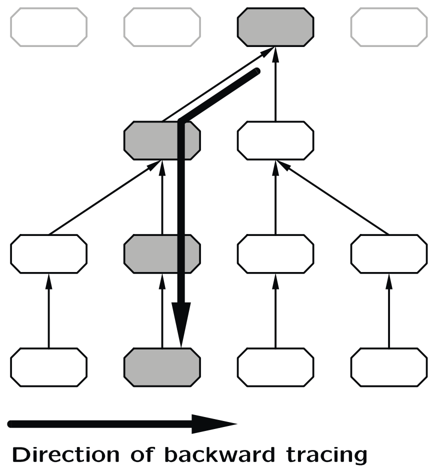

Figure 2 – Backward tracing in a *gozinto graph* of individual items

Since rudimentary tracking and tracing was already introduced in an era where most of the reporting activities were *paper-based* (i.e., they rely on printed or written documents whose electronic presence is secondary), or required *human intervention* (e.g., filling in delivery documents, reading identifiers or manually entering data into computer systems; but in most cases, even reading bar codes needs a share of human assistance). As the requirements grew more and more intricate, the growing occurrence of malfunction phenomena shed light on the weak spots of "manually maintained" tracking and tracing (Hewlett-Packard, 2004):

- labour costs associated with logistics administration are high;
- substantial time lags occur in the information available on shipping progress;
- data loss or corruption due to human error is encountered.

These drawbacks of paper-based or manually documented transactions may impair manufacturing and delivery processes in several ways:

- "malfunctions" (i.e., late or wrong deliveries, stolen, lost or counterfeited shipment units) may not be detected in time;
- locating goods within the supply chain is difficult and unreliable;
- imprecise delivery data imply false forecasts, resulting in ill-dimensioned orders, and exposing the supply-chain to the "bullwhip effect" (see also Dejonckheere *et al.*, 2003);
- sparse knowledge of logistics operations may result in less-than-optimal planning and exploitation of transportation resources (large amount of deadheading transportation).

All this can add overheads and errors which would seriously impair the competitiveness of a manufacturer or logistics service provider.

2.2. ADVANTAGES OF AUTOMATIC IDENTIFICATION (AUTOID)

The above mentioned disadvantages can be overcome by minimizing human intervention and the number of otherwise unreliable and slow interfaces (Kärkkäinen *et al.*, 2002). In practice, this means that the identification of goods and their association with the progress of physical delivery have to be automated, requiring automatic identification (AutoID) with as little human intervention, paper-based or lagging data transfer as possible. AutoID techniques (such as radio-frequency identification—RFID—or barcodes as a fallback measure) can offer the following features for the benefit of manufacturing and delivery processes:

- higher feasibility of an optionally unique identifier on a given shipment level (batch, item etc.);
- automatic association of a reading transaction with its time and location;
- transferring (reading or writing) further data with the same physical ID carrier (may not be available for certain carrier types).

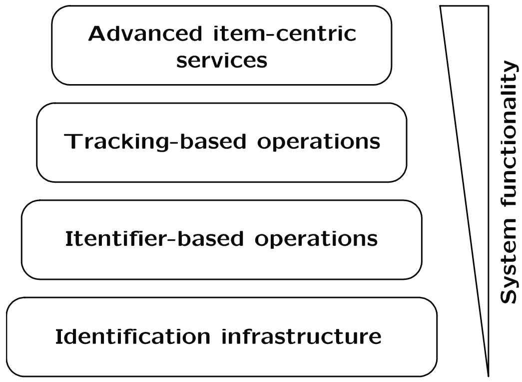

Figure 3 – Functionality layers of activities based on identifiers (AutoID); an extended view of the original classification scheme by Kärkkäinen *et al.*

In a few simple cases, the *presence of an identifier alone* can already solve some problems—e.g., "go/no-go" decisions based directly on an ID and not some other associated data (lowest layer in Fig. 3)—but in most cases, it does not pay to remain on this rudimentary layer of functionality. In fact, investment in an AutoID technique usually involves, at least, simple *identifier-based services* (second layer from the bottom in Fig. 3) which use, at least, a facility-level database of the items present on site (account-oriented material management) and can be considered a quantitative improvement of existing transaction structures.

A further step towards enhanced functionality is the *use of location and time information associated with a given reading transaction of an identifier*, as using this information, the movement of goods can be tracked, hence the name *tracking-based operations* (second highest layer in Fig. 3). Performing this operation with the assistance of AutoID techniques can potentially eliminate a substantial portion of today's supply chain problems as bottle-necks inherent to paper-based or manual transaction processing exhibit most of their drawbacks on this level, as already addressed earlier in the paper.

Further sophistication, pointing towards tracing, is typically attributed to the highest level in the hierarchy (see also top layer in Fig. 3), i.e., *item-centric services* (Kärkkäinen *et al.*, 2003b). Most important for supply chains is the fact that on this level, identifiers are employed to distinguish *items* (individuals or, in general, smallest units whose separate handling would pay in the given scenario) as opposed to classes or batches which often prove sufficient if only lower-level functionalities are in the focus of interest. Although item-level identification does require significant development in the information architecture behind the transactions, it allows the participants, in turn, to establish the state-of-the-art in tracing services which can grant superior efficiency in quality control (product recall can be initiated in time and is restricted to the smallest possible volume, due to the exact knowledge of goes-into relations; quality control and process optimization can be supplied with accurate and up-to-date information etc.) and optional services for customers (exact knowledge of the status of an order, improved after-sales services etc.).

Today, most common applications among AutoID solutions are identifier-based and tracking-based operations. While barcodes and other optically readable labels are now widely accepted (note that it took them a decade of preparation to become commonly used within a brief period of time), RFID—which would unfold the full potential of completely automatic identifier detection—is still not fully established, due to a variety of reasons:

- the price of RFID tags still transcends the feasible maximum for item-level identification (mostly, about 5–6 times too high);
- regional differences still exist with respect to allowed operating frequency, and several (competing) numbering schemes are used worldwide, such as the system of EPCGlobal and the ISO-supported standard;
- RFID tags cannot be applied with materials of some critical electromagnetic or dielectric properties (although recent years witnessed much improvement in this concern);
- reliability of some tag types still needs improvement (in some cases, however, it is possible to use other ID techniques as a fallback measure);
- security issues (easier disclosure of confidential manufacturer data, either due to insufficient encryption, or due to fast and automatic reading by third parties) and privacy concerns (individuals fear to be tracked down without their consent or knowledge) still impose barriers on wide acceptance of the technology.

2.3. BARRIERS OF THE PENETRATION OF AUTOID TECHNIQUES

In general, it can be observed that massive application of RFID is prevailing in big companies which, in turn, force their own tracking and tracing system upon their suppliers. This is due to the fact that, without a widespread and versatile enough off-the-shelf solution, tracking and tracing applications still emerge in isolated, proprietary development which does, usually, not keep compatibility to other solutions in mind. All this lets one conclude that, even though the technology is present and its penetration is growing, there still exists a barrier which small and medium-sized enterprises (SMEs) can rarely overcome (Stefansson, 2002)—even though efficient tracking and tracing beyond company borders will be of vital importance in the production networks and supply chains of the next future (Kärkkäinen *et al.*, 2003):

- high initial investment is required to build a specific information infrastructure;
- costs of registration with central ID providers are, mostly, still too high;
- systems and practices already in use differ from company to company;
- prospective participants are afraid of exposing confidential information (e.g., delivery data in a machine-readable form) to unauthorized third parties.

3. GOING BEYOND THE STATE-OF-THE-ART

The above situation, certainly most adverse to smaller enterprises, can only be overcome by going a step further than today’s state-of-the-art—but still proprietary, and in most concerns mutually incompatible—tracking and tracing solutions by offering a platform which is standardized but flexible enough to cover the needs of a considerable range of SMEs, so that closer collaboration can effectively occur. Apparently, the initiative for such development must be first taken by the research community which has the potential of bringing forth—while receiving the necessary feedback from the industry—a solution platform and a knowledge repository which can bridge the technological gap caused by the sparse spreading of AutoID-based tracking and tracing among SMEs. The three-year project TraSer, funded within the EU 6th Framework Programme, was called to life with exactly this purpose (see also http://www.traser-project.eu).

The consortium of the project comprises three academic partners, namely: the coordinator MTA SZTAKI (Computer and Automation Research Institute of the Hungarian Academy of Sciences) which has industrial experience with supply-chain-related solutions; HUT (Helsinki University of Technology) contributing to the project with the progressive theoretical fundament of item-centric tracking and tracing; and RuG (University of Groningen) providing up-to-date contributions about currently available standards and technologies. Four industrial partners are members of the consortium as well who represent a range of industrial requirements and provide the opportunity of testing the project’s products in real-life pilot applications:

the Dutch research company TNO, the Hungarian design and prototyping company Innotec, the Finnish Post, as well as Wittmann & Partner Computer Systems of Romania.

3.1. GOALS OF THE TRASER PROJECT

3.1.1. The TraSer software package

Based on experience gained with an earlier development of the Helsinki University of Technology, the DIALOG system (see the DIALOG Project Website, http://dialog.hut.fi), the main output to be issued by the end of the project is a free, open-source solution platform for tracking and tracing applications on the item level. The platform, providing the background for tracking and tracing in the form of web-services, will suit the industrial needs represented, especially, by SMEs, and can be used to build a network of *TraSer nodes* (i.e., servers storing and providing access to material information on the item level) and *TraSer clients* which can read or update information stored in the nodes (as shown in Fig. 4). The software package is planned to offer advantages and features as explained in detail below.

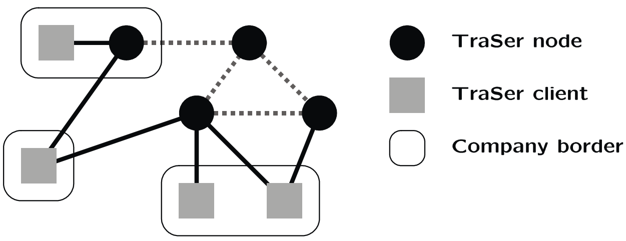

Figure 4 – Composition of a TraSer network consisting of nodes and clients

Low costs of installation and operation will be required, thus, avoiding the burden of high initial investment and costs of a large IT specialist staff which is associated with the maintenance of unique proprietary solutions. This is, primarily, due to the platform being open-source and easy-to-install. Since the TraSer software will be offered as an off-the-shelf package, users can exchange experience with each other and with developers, contributing to an easier location and avoidance of known problems.

Operating costs can be additionally reduced through the use of the *ID@URI identifier notation*, as proposed already earlier by HUT, since this allows the users, under proper circumstances, to generate their own *globally unique item identifiers without the need of registering with an ID provider*. This is made possible by the uniqueness of a URI which points to a location where access to the given ID (unique for the given URI) can be requested. It is easy to recognize that this notation intrinsically corresponds to the web-service nature of data traffic as envisaged for TraSer. However, this does not imply confinement to only one numbering scheme—while relying on ID@URI as an internal notation, TraSer will allow the use of other external numbering systems as well.

TraSer will be able to communicate with *already existing systems*, such as enterprise resource planning (ERP), or other tracking and tracing networks already in use. This is made possible by the open specification of communication interfaces, allowing users to create adapters connecting their TraSer software to already existing applications. Using such adapters, it will be possible for TraSer to act as a bridge between different networks of tracking and tracing services (Fig. 5). Also, the open specification of the software will *allow users to reimplement the solution platform in their environment of preference*—a requirement characteristic to companies where a longer past of IT practice may imply either adherence to a preferred environment or reluctance to add yet another new element to an already heterogeneous conglomerate of IT tools.

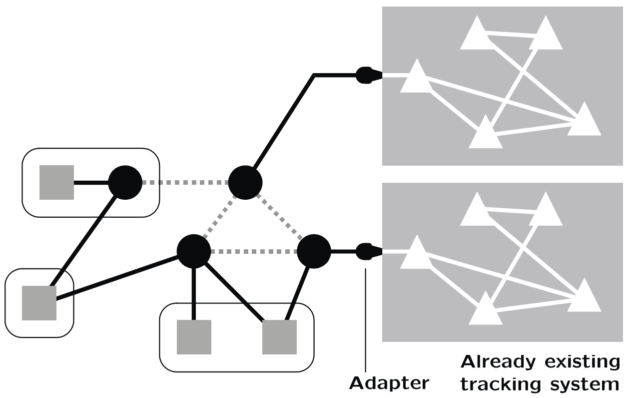

Figure 5 – Coupling of already existing components and networks to TraSer nodes

Data security is one of the most important requirements of an industrial application which handles confidential information. In TraSer, this comes down to three aspects: *i)* data obtainable from the identifier tags, *ii)* data transmitted during network communication, and i*ii)* access to services provided by nodes. The protection of identifier data has gained importance due to the fast access and easy aggregation of identifier data made possible by AutoID techniques, especially RFID. In order to protect a given identifier (especially the URI designated to the manufacturer) from being collected by unauthorized parties while still allowing the use of simple passive RFID tags, the compromise of a *fixed encryption key* (as opposed to zero-knowledge encryption) may be used upon demand which trusted parties of a given group of activities may use among each other. The encryption of network communication channels is no new challenge; in fact, a wide variety of off-the-shelf solutions is available and can be integrated into the data security functionalities of TraSer. As for services offered by nodes, TraSer will offer the possibility of freely configurable access control, allowing users to assign access rights both on an individual basis (client by client and item by item) or using rules. If a given node belongs to several groups trusted in different transactions, it will appear to its communicating parties as a set of virtual nodes, each serving its own group of trusted partners, without revealing communication activity to unauthorized parties of other groups (Fig. 6).

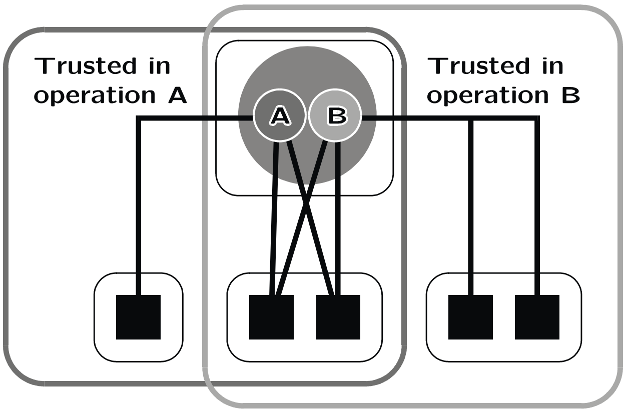

Figure 6 – A TraSer node appearing as two virtual nodes to members of different authorization groups

Another crucial issue in software supporting business processes is *data consistency*. This is of special importance in TraSer, since here, nodes and clients can often span large networks (of possibly varying connection reliability) with several participants involved in series of transactions belonging together. To guarantee consistency, one could rely on a variety of techniques. First, transactions could be planned to be fault-tolerant, e.g., by separating activities (especially updates) in smaller independent blocks where consistency is easier to ensure. Second, one can impose limitations on network activity rights, especially with respect to data updating (writing) transactions. This may range from a simple policy of keeping the set of authorized clients as small as possible to placing a special client in a *host role* (Fig. 7) with the sole task of ensuring consistency before an update transaction. In the latter case, only hosts would have the right of initiating updates with the nodes—which they would use when all the update requests of a given transaction round, as received from non-host clients, comprise the desired consistent state. (Note that even in this case, all trusted clients would still be able to retrieve information independently of other client activities.)

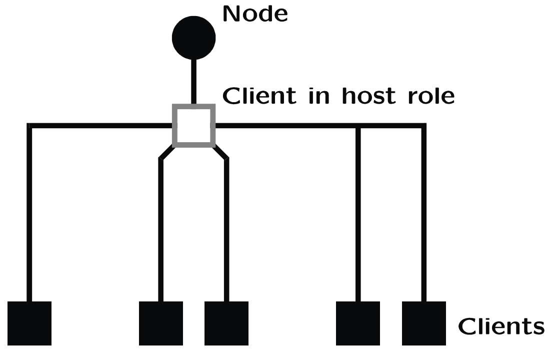

Figure 7 – A client acting as a host ensuring consistent update requests towards a TraSer node

The introduction of item-level storage, as opposed to currently widespread account-based or batch-level resolution, multiplies the amount of data stored in the system by at least an order of magnitude. To cope with this challenge, the TraSer network—as opposed to today's practice—will use *on-demand data delivery in conjunction with advanced caching functionalities* to keep network traffic on a low level while still being capable of delivering business-critical data on time. Data that are not subject to changes over time can be effectively cached on remote sites, while critical data whose accessibility must be granted even during network failures can be duplicated in the system.

The success of such a framework as the TraSer platform depends much on its ability of handling data models which may be different in every branch of industry and may even vary from company to company. Coping with such challenges needs *i)* flexible scheme and interface definition possibilities, as well as ii) means of mediation between different models. The TraSer platform pursues a *modular scheme and interface definition* which allows an open network of TraSer nodes where participants with various capabilities regarding communication and track and trace applications can be integrated. However, the use of different schemes would hamper the possibility of data storage distributed over several nodes, or composing an integrated view of data stored in various nodes. These difficulties will be handled by *mediation*, i.e., translating or mapping one scheme onto another and thereby preserving the meaning of data in different representations.

3.1.2. Towards an open-source community

The TraSer solution platform is not the only product to be offered for industrial users. Since nowadays, few of the SMEs have sufficient knowledge about tracking and tracing practice, it is—not only for the success of the TraSer solution platform—vital to provide *information material* which enables prospective users to acquire specific knowledge on their own. For this purpose, a collection of case studies, presentation of best practices and various manuals and instruction material will be made available to the users, covering both tracking and tracing practice in general, and issues specific to the application of the TraSer platform. Aside from an initial collection of supporting documents, new experience is also planned to be integrated, gained by users as well as experts taking part in the development of the solution platform and its accompanying knowledge repository.

Aside from written material, the opportunity of *workshops* is provided as well. In the initial phase of the project, workshops held with prospective industrial users will help the project participants to gain insight into relevant requirements and concerns of the industry, which not only improves the understanding of the underlying theoretical and practical problems but also results in a solution platform which is fits the challenges industrial grade application better than a “clean-room” development. In later phases of the project, workshops will primarily have an information and instruction nature and will thus extend the range of written explanatory material created for the users.

The final goal in terms of user–developer interaction is the establishment of an *open-source community*. Here, users will be able to share their experience, as well as contribute with self-developed extensions of the basic software package. Also, users could receive answers to their specific questions either from more experienced users or from the developers of TraSer themselves.

3.1.3. Opportunities for research

Aside from benefits for the industry, TraSer will offer research opportunities as well, giving a detailed insight into the functioning of production networks and distributed document storage. As a result, scientifically founded ways can be found to motivate companies to become involved in tighter network integration, e.g., by giving guarantees and using transaction protocols or access control schemes which provide reasonable safety where it is truly needed. Furthermore, commercially common “best practices” and technological solutions can be designed which may facilitate the composition and gradual improvement of network-level services. Due to the close relations of the above subjects and industrial practice, research (as well as development) conducted in TraSer will be iterative, supported by frequent feedback of real-life experience, as proposed by Kaplan (1998) in the *Innovation Action Research* (IAR) approach.

3.2. APPLICATION PILOTS

3.2.1. Tracking of physical items

A proposed RFID pilot for tracking physical items will build on an ongoing project with Finland Post focusing on recyclable container asset management. Here, recyclable containers are tracked through loading, shipping, delivery, and return to the terminal. Gate readers at three gates of the same facility and hand readers distributed among customer sites are applied to obtain the identifiers of the containers, resulting in tracking events which are to be registered in an item-centric database. If the RFID evaluation currently in progress at Finland Post is successful, the future investment path of the company will follow three time horizons:

Phase 1 (present to 2010): Recyclable transport units are equipped with RFID tags and gate readers are installed in company-internal facilities, and handheld terminals are upgraded with RFID for partner use. Primary purpose is improved han-dling efficiency and asset management.

Phase 2 (present to 2010s): Attach RFID to individual shipments (parcels, newspaper stacks, recommended letter) with the objective to improve tracking and tracing for customers. This phase corresponds to the basic scenario in the TraSer project.

Phase 3 (present to beyond 2010s): Introduction of item-centric control into the process. The goal is the introduction of value-added services—e.g., merge-in-transit and vendor-managed inventory—across the participant network. This phase corresponds to advanced scenarios in the TraSer project.

As it can be seen, the physical item tracking pilot in TraSer is connected to phases 2 and 3. The important objective of the pilot in TraSer is to determine how efficient RFID is to address the development challenges of these phases.

3.2.2. Tracking of documents and product data

Companies involved in a production network and collaborating in the development of common products are likely to need a shared framework for exchanging and keeping track of blueprints and other product data, facilitating easier retrieval for later phases of the product lifecycle and combination of plans for customized products. Attaching identifiers to the electronic documents, similarly to tagging physical items with barcode, RFID etc., is assumed to transform the problem into a task which can be handled by a TraSer network.

The industrial partner INNOTEC will host such a document tracking pilot, and is taking part in the specification of the TraSer platform requirements as well. The product data tracking pilot will examine such main questions as:

- What data are necessary and important to be recorded for unambiguous file identification, with respect to time of creation and contents?
- How should the information be structured and visualized on the user's computer?
- How can a common structure for the storage and management of data for different types of CAD systems be developed?
- How can the approach be generalized for other types of digital data?

Transferring product information between network members is technically challenging as the distributed storage of information—often in multiple copies—does not even align with the first normal form of databases and updating anomalies are frequently encountered. Difficulties also show in practice, e.g., by current STEP implementations, where setting up and maintaining information links is costly and time consuming for all participating companies. Even though information links exist, handling changes in products and in the information about them is not an easy task, especially with respect to updating multiple copies which reside at different participants of the network.

The quickly advancing availability of the Internet (at least in the industrial context) is one of the factors potentially contributing to the success of the pilot, as it allows remote access to product information throughout the entire supplier network and thus reduces the amount of multiple copies. Many companies already have existing product data management (PDM) systems and associated web services where product information is accessible, similarly to ERP systems and isolated tracking and tracing solutions in the case of physical items. Therefore, the TraSer solution platform must be prepared to adapt to these conditions, as well as allow both centralized and distributed physical storage of documents, whichever suits the user best.

4. CONCLUSION

Recent development of industrial production presents an ever-growing demand for tracking and tracing of work pieces, documents etc., more and more often beyond company or organizational borders. While identity-based tracking and tracing is already applied in industry, several—mostly cost-related—drawbacks confine it to isolated proprietary solutions applied at large companies, while SMEs venture the step of investing in present-day ID-based tracking usually due to the pressure of their larger customers only. The EU-sponsored project "Identity-Based Tracking and Web Services for SMEs" (TraSer, see http://traser-project.eu) is aimed at overcoming this obstacle by providing an easy-to-maintain open-source solution platform for tracking and tracing applications. The TraSer system will be based on experience gained with an earlier development of the DIALOG system and will, similarly to DIALOG, set up an open-source community where potential users from the industry can share ideas and experience with developers and researchers. The practical feasibility of the TraSer platform will be tested and improved to industrial acceptance in pilots such as product tracking in forwarder-independent shipping and merge-in-transit scenarios, as well as product data tracking for management of CAD drawings.

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