IDENTITY-BASED, ITEM-CENTRIC TRACKING PLATFORM FOR LOGISTICS APPLICATIONS

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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, as well as state-of-the-art of related topics.

Keywords: AutoID, track-and-trace, open-source, cross-company interoperability

1. IDENTIFIERS AND IDENTIFICATION FEATURES

1.1. Why are IDs needed?

The most fundamental requirement to be met before establishing tracking is the agreement upon a common identification system, consisting of:

- one or more standard types of physical ID carrier, and
- one or more ID allocation scheme which all users can interpret.

The presence of an identifier can trigger ID-specific actions, and together with proper location information, time stamp of detection etc., it can provide input to make tracking services work and keep them up-to-date.

1.2. Properties of identifiers used

Various means of identification offer different functionality levels which may be exploited in operations based on unique identifiers. Below, the main groups of these features are listed. In (Ilie-Zudor et al. 2006), a similar grouping is presented with corresponding application examples specific for the case of RFID.

Unique identifier. This is the ability to provide an identifier which makes it possible to unambiguously mark a given item and set it apart from others within the range of the whole identifier-based system. This is the key property which is most needed when identity based services or operations are performed, and as it can be seen, all groups of physical or electronic carriers examined offer this feature.

Location and time information. Associating a location and time information with a given identifier can be carried out in two possible ways: i) Recognizing an item with a reader of a specified physical location at a given point in time allows us to imply that the recognized item (at least, the identification carrier meant to identify it) was physically present at the specified place and time (e. g., an item passes through a gate reader of fixed location which reports its occurrence automatically). ii) Knowing that a given item is attached to a kind of carrier whose location at certain points of time is known (e. g., a vehicle transporting the items, or a directory containing several documents), it is not necessary to identify the items during the transfer since it can be assumed that all originally contained items (e. g., articles locked into a vehicle) change their place together. Here, it is sufficient to report the progress of the carrier only (optionally, along with the identifiers of the items carried) without any repeated identification of the items taking place.

Transfer of further data, read-only. In some cases, not only an identity is extracted from the physical carrier but also auxiliary data are read which would be difficult, impractical or too costly to obtain from a remote or pre-recorded database. In these cases, the physical carrier of the identifier works, in essence, as an additional read-only data carrier as well.

Transfer of further data, read and write access. A further group of cases makes refreshing the aforementioned additional data necessary, which would call for a physical carrier functioning as a read-write data carrier as well. While this is no problem with rewritable RFID tags or purely electronic identifiers, other carriers (e. g., bar code) can only offer the workaround of re-labeling.

Transfer of further data, in-situ update. Although relatively rare, it may be needed that additional data attached to identifiers change their contents autonomously and allow, e. g., the automatic recording of changes in the state of the item in question. Such a case may occur if chemical containers need to be equipped with RFID tags which can transmit the current temperature etc. to the reader, or if special tags are used for quick diagnostics of livestock etc. Of course, pre-printed physical carriers with fixed contents (e. g., barcode) cannot support the realization of this functionality.

Changing the identifier. In some cases, items need to discard their old identity and take on a new one (e. g., assignment of an item to a new responsible entity). This is seamlessly supported by re-writable RFID tags and purely electronic identifiers while other kinds of physical carriers (e. g., barcodes, non-rewritable RFID) would need a workaround by relabeling.

Table 1 summarizes the above properties with respect to their availability with various physical ID carriers, while Table 2 lists which properties are needed for different levels of functionality which rely on item identification.

Table 1: Possible support of various identifier properties

Property used	RFID	Barcode etc.	Human-readable	Electronic ID
ID	+	+	+	+
Location/time	+	+	+	+
Further data, R	+	+	+	+
Further data, R/W	+	W	W	+
In-situ update	+	–	–	+
Change of ID	+	W	W	+

\+ supported
– not supported
W workaround (re-labeling) needed

Table 2: Required and possibly exploitable properties for various functionality levels

Functionality level	ID	Location/time	Further data, R	Further data, R/W	In-situ update	Change of ID
Identifier-based operations	+	–	*	*	*	*
Tracking-based operations	+	+	*	*	*	*
Advanced item-level services	+	+	*	*	*	*

\+ required
– not needed
* may be exploited

1.3. Application of identification architectures

Although the mere presence of a technical background for item-level identification forms a separate layer of functionality, it is hardly used alone. This is, in the first line, due to the fact that item-level identification in itself is rarely sufficient for desired functionalities and investing in ID carriers and readers alone makes only sense in some specific cases which are a rare exception to the above rule. This occurs when the reader (or a dedicated device coupled to the reader but having no connection to a database or a comparable repository) is able to decide on the spot what action has to be taken upon a given item's detection.

One of the most common examples mentioned in literature are RFID-based anti-theft solutions (Modern Purchasing 1993) where readers may react on a given subset of identifiers only (which are not even required to be unique)-these, of course, do not necessarily need to be obtained from a common repository and may reside pre-loaded in the hardware accompanying the readers.

Although only fiction now, many other uses are envisaged for the future. Recipe parameters (e. g., baking time) could be automatically read and forwarded to the appropriate device (Almirall et al. 2003), another interesting application is envisaged for washing machines where read-write RFID tags in clothes also record how many times the given piece has been washed and select the proper washing program to adapt to aging of the fabric (RFID Journal 2006).

One of the most unusual examples is the graphical tablet (Graphire pen functionality 2006) used as an input device for computers. Here, the identifier may prevent the stylus or mouse from being swapped or accidentally read by neighboring readers or may define the type of the input instrument, while additional measurement data (such as stylus tip pressure or a list of buttons pressed) can be transmitted to the reader in addition. The reader is implemented in a special form which can determine the exact spatial position of the input instrument within the borders of the tablet-this is rarely the case for commonly used readers; comparable plans are only found in the proposed idea of a triangulation-based location system using direction-selective long-range RFID readers for finding golf balls lost on a golf course (Transponder News 2005).

1.4. Application cases of ID-based operations

Identifier-based operations have a longer tradition in asset management than in supply chain management. The most simple cases of identifier-based asset management tend to be so rudimentary that it becomes difficult to draw a distinct border between the local use of identifier architecture (Figure 1) and actual identifier-based operations (Figure 2) supported by a facility-level data repository.

Common to all of these is the lock functionality, focusing on the binary question of a given individual (or a member of a given class) being inside/outside, or entering/leaving the given facility, (e. g., whether a given tool is inside the storage room) often in conjunction with a go/no-go type authorization of further operations (e. g., personal RFID cards widely used in access control of buildings, restricted use of computers or other tools etc.). The key question setting actual identifier-based asset management operations apart from a mere local use of identifiers is whether or not there is a facility-level information architecture informing the reader of possible actions to be taken locally (e. g., granting access) and, optionally, gathering data about entities transferred through the reader-equipped locks at the facility borders (potentially resulting in binary information about a given entity being in the facility).

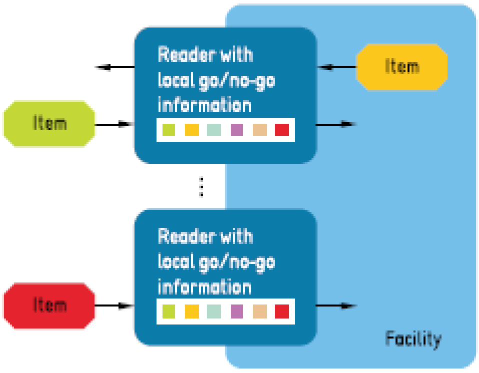

Figure 1: Local use of identifiers in asset management

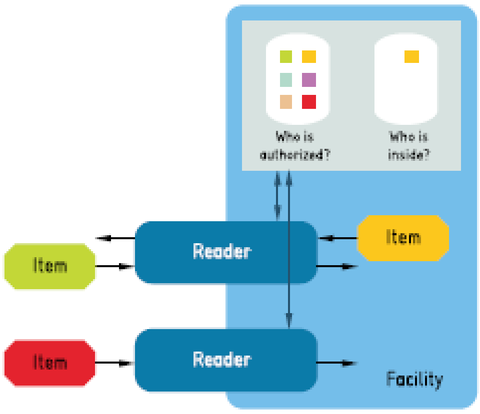

Figure 2: Identifier-based operations in asset management

Therefore, the most simple identifier-based anti-theft systems would rather qualify for the local use of identifiers while more elaborate access control (even a multilevel example for organizing a conference in China (Furness et al. 2005) and contemplation of RFID-aided house arrest supervision (Transponder News 2005) are known) would already require a central piece of hardware supervising the readers and thus belong to the class of ID-based asset management operations.

One of the most elaborate and interesting examples for ID-based asset management-personnel management, to be more exact-is used by the shipping company TNT at the Helsinki Airport (RFID Lab Finland 2005). Here, security guards are required to patrol the facilities along a specified route to ensure the security of the logistics center of the company as well as other personnel. In order to control the work performance of the guards, each of them has to operate a portable RFID reader to detect tags placed along the required path. Each reader stores a list of the checkpoints passed, and the list can be acquired from the mobile readers at a given point of time (e. g., end of shift, end of one patrol etc.), and stored in the central records. In this arrangement, the mobility and connectivity of individuals and readers is "turned inside out" compared to the common arrangement, and instead of network connections, the mobile readers and the staff themselves convey the data.

Other examples of ID-based asset management are aviation service provider Nordam's more reliable tool collection system (AMT 17/3), and the improved access authorization procedure at the Californian harbors (Innovate Forum 2006). In the agriculture, farm animals can be identified using RFID tags, and a retrieval service for lost pets also relies on RFID implants as the means of identification ('Home Again' pet retrieval service (Home Again 2005), although in the latter case, the presence of location information and a widely accessible database may rather resemble the next level of functionality, i. e., tracking-based operations).

In supply chain management, most ID-based operations-keeping original organizational structures-are grouped around inventory changes or updates, related to what entities enter, reside in, or leave the inventory. In most cases, this calls for a more elaborate database than in the case of asset management with binary go/no-go or presence indicators, as in account-based stock keeping, several items of the same class are grouped and each of such classes may have its own supply level information, handling instructions etc.

A typical example of RFID-aided inventory management on the facility level is the RFID test case introduced at the Dutch book store Selexyz. The books headed to the pilot store were equipped with passive RFID tags before packing at the distribution center of a third-party-logistics service provider specialized in books. The tagging allowed the automation of the receiving of books at the store, which previously relied on manual bar-code reading. Now, the boxes containing the books can pass unopened through an RFID reader port, thus reducing the time needed to register which items entered the store upon a given delivery. The second major area of improvement is the inventory counting, which can be performed with portable RFID readers in a few hours instead of closing the store for a day. Due to these improvements, the need for staff in the book store has dropped from 22 to 15, and Selexyz has decided to expand the system to other stores (Trebilcock 2006).

Other examples for similar ID-based support for receiving and inventory counting operations can be found at the clothing stores Kaufhof (Roberti 2006), Marks & Spencer (Frontline Solutions 2005) and Levi's

(Frontline Solutions 2005b). Receiving is accelerated using RFID technology at Wal-Mart (Chain Store Age 2005) and Metro (Hoffman 2006). Manufacturing processes with a flow-through of material can benefit from identifier application as well, facilitating such solutions as automatic retooling of work-cells for the given item, and fail-safe identification of samples for quality control (Schreiner's LogiData control system applied by Auto5000 GmbH, a supplier of Volkswagen (RFID International 2005)); RFID-based administration of quality control at Ford's Essex engine plant in Windsor, Ontario (Furness et al. 2005); RFID-based identification of material test samples at the MTR Corporation of Hong Kong which builds and operates urban railways (Furness et al. 2005)). Closely related are also the DoD standards for product vendors (DoD 2004) which allow an identification of origin and also facilitate the in-transit tracking of goods which will be the focus of the next section. Generic value chains form a special application group, with such examples as architectural construction processes (Skanska Finland applies Enterprixe's 4D production model solution).

2. TRACKING-BASED OPERATIONS

2.1. Functionality

Tracking-based operations are primarily focusing on the movement of material within a network of various locations. In this context, the point of view of identifier-based operations concentrating on inventory changes of a given facility is, in some way, representing a dual to the attitude of tracking-based operations where the materials themselves form the main subject of observation and location information is represented as a property of the given individual. This change of perspective is necessary because this level of functionality requires the individual items (or batches of items which have their own identity) to be recognized and tracked as such across a series of locations-plain account-based material management is not suitable for the realization of this level of control (Rönkkö 2006).

2.2. Requirements

The realization of tracking-based operations requires the following preliminaries:

- Identifiers unique to instances or batches which can be successfully read at all locations and times in concern;
- Infrastructure and common methods/protocols of acquiring and forwarding the time/place information associated with reading an ID;
- A database of central role above the facility level (note that physically, it may be of a distributed form) where subsequent location/time marks associated with the given ID can be aggregated and are available for surveillance and further processing.

2.3. Advantages

The primary advantage of performing tracking on the level of items or batches (instances, in general; as opposed to class cardinality with account-based operations) is that the path or the presence of material can be tracked with higher accuracy than that of conventional structures. As a consequence of aggregation over all locations involved, detailed material-related information can be acquired and processed more efficiently, which in turn facilitates better decisions in material management and related issues, ranging from more efficient logistics in supply-chain management to optimized usage of material in asset management.

In the current material handling scene, account-based solutions still prevail, yet the direct or implied advantages of item-level tracking are clearly effecting its gradual spreading in cases where these advanced functionalities are worth the investment.

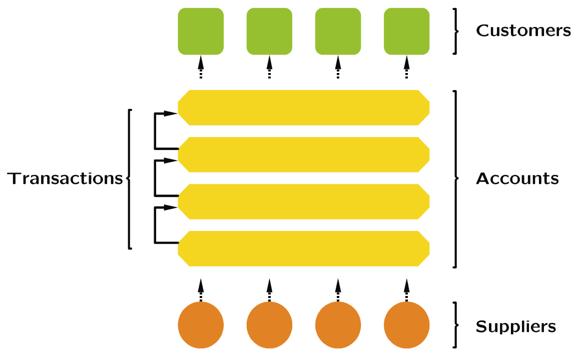

Figure 3: Account-based material management

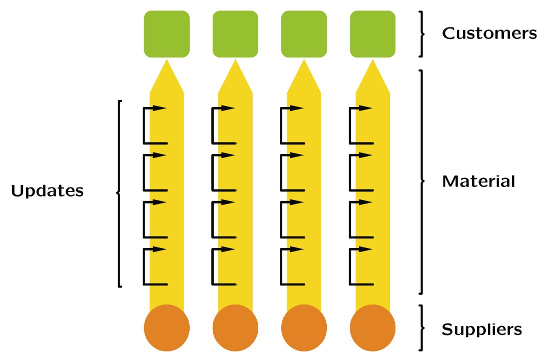

Figure 4: Item-centric material management

3. ADVANCED ITEM-CENTRIC SERVICES

3.1. Functionality

The next step in achieving higher-level functionalities is the integration of tracking and related services transcending either organizational borders (typical for supply chains) or functional borders within the same organization (typical for closed-circuit asset management), as shown in Figure 5.

This extended transparency (and not less the fact that groups which have to do with the same item in different ways-e. g., manufacturers, forwarders, retailers, users-can access information about the item) gives the opportunity to establish advanced services on the item level (referred to as item-centric services) which go beyond the usual functionalities of pure tracking. As far as their access rights allow, various user groups can then either update (e. g., notification about the item passing through production stages) or read (e. g., inquiry about availability or delivery status) item-related information. Currently, a significant part of these elements is already in use in various branches of industrial production, yet they are kept from unfolding their full potential because only partial solutions are present, isolated from each other by organizational or functional borders which can be-if feasible at all-transcended by manual intervention only.

3.2. Requirements

As it can be expected, the additional requirements for integrated item-centric services revolve around establishing transparency through organizational or functional borders:

- Infrastructural requirements for transparency, such as interfaces and protocols in simple cases, and higher-level standards of mutual agreement, such as common ontologies if complex operations are required;
- Differentiated access control for user groups with various levels of authorization, requiring authentication, authorization and protection of communicated information (including identifiers).

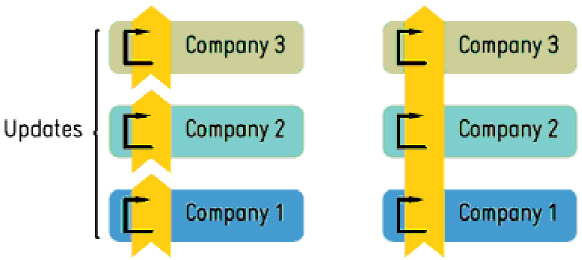

Figure 5: Tracking of material (yellow) interrupted at organizational borders (left) vs. integrated services transcending borders (right)

3.3. Advantages

Transparency transcending organizational or functional borders has received much attention in recent literature, as it is essential for improving efficiency in processes which, even if not tracked directly, do pass through these borders anyway. The successful control of such processes depends on decision makers or controlling mechanisms having a proper overview over events or processes concerning the subject of the transactions (observability, in a control engineering perspective (Dejonckheere et al. 2003)). Once this is provided, better decisions can be met for planning such processes as

- assignment of work and assets depending on limited resources;
- transfer or allocation of assets to meet current and future demands for closed-circuit asset management,
- order and work forecasts;
- optimization of transportation processes;
- processing of customized orders;
- quality feedback;
- "fault-tolerant" composition of products and production steps for supply chain management.

It is also worth examining the interfaces needed for transparency. In the most simple use cases, a web interface is sufficient (occasional use, such as checking order status by customers), while a long-lasting business-to-business relationship can exploit the benefits of closer system integration and thus relieve the involved parties of the drawbacks of manually controlled operations (time lags, human errors).

A company extending tracking services to its customers is able to provide the service only from the parts of the supply chain which are connected to the same tracking system, using the same notations and databases. Therefore, the most beneficial services can be built when the handling parties in the supply chain agree to share an integrated tracking system or one company is vertically integrated over a large part of the supply chain (see Figure 5).

4. AN IDENTITY-BASED, ITEM-CENTRIC TRACKING SOLUTION IN SUPPLY-CHAIN MANAGEMENT

4.1. Concept overview

This section details an approach under development of an open source platform which is created in order to support SMEs in the adoption and development of tracking-based logistics applications combining mass customization and mass collaboration features.

There are benefits for all types of economic actors if the technological problem of tracking in changing networks is solved. Smaller corporations could participate in temporary networks more easily, while large corporations could introduce advanced operations on a wider scale, and start to benefit, for example from Vendor Managed Inventory (VMI), and provide after sales services to more customers.

The solution focuses on forwarder independent product individual, shipment or product-data tracking. The forwarder independent tracking solution consists of two types of easily installable software components: checkpoint clients and server components. The checkpoint clients are used to register the movements of material and inventory status in a supply network, and the server components (i.e. the middleware) receive information from the clients and pass it to business applications.

For tracking-based logistics service solutions to be effective and valuable in temporary and changing participant networks is required that:

- The applications are product centric, rather than provider specific. The reason is that product centric applications facilitate solutions that can be used at different stages of the product life cycle and by actors that are not needed to be specified in advance.
- Service providers develop capabilities for efficiently setting-up identity checkpoints for product centric applications and for interacting with this novel type of applications.

The key point that takes the proposed research beyond the state-of-the art is illustrated in Figure 6 for logistics services. The unique address-code attached to the physical product, and the checkpoint client available for download on the Internet makes set-up and integration extremely cost efficient.

This solution is more portable than trying to communicate directly with the Application Programming Interfaces (APIs) of different ERP systems. If such communication is necessary in some application (e.g. real-time applications where very rapid reaction by the ERP on incoming events is required), then that can be provided by an application-specific 'agent' that registers with the platform for receiving such messages.

The approach taken in the solutions targeted, builds around the so-called 'product-centric' concept. This concept signifies that information about any individual product item (including product types) can be accessed over a network connection if the product item is identified properly. The approach is not limited to tangible objects; it could also be applied to documents (e.g.: CAD drawings).

In order to make this possible, globally unique item identification becomes necessary. In the solutions proposed the ID@URI approach (Furness et al. 2005) is adopted and further developed. In this notation the ID stands for an identity code of the consignment, and URI stands for the Internet address of the computer to which the information should be sent. This ensures that the system can be used with several partners and, also, that the uniqueness of tracking codes can be managed. When using URLs (Uniform Resource Locator) as URI (Uniform Resource Identifier), the network address where the information can be accessed is directly indicated. Since a URL must be globally unique by definition, it then becomes sufficient to use a unique ID for that URL to make the identifier globally unique.

The development of the concept proposed is being done as part of an international project, titled Identity-Based Tracking and Web-Services for SMEs (http://www.traser-project.eu).

The main scientific research objective of TraSer is: Gaining insight into possible ways of motivating prospective partners to participate in network-wide information sharing (such as through scientifically founded guarantees for safe and efficient operation).

The technological objectives are:

- Assessing possibilities of integrating item/centric concepts into an existing transaction-processing scheme;
- Providing scalable and flexible access control while complying with industrial security requirements;
- Exploring and applying best practices for realizing network-level services in heterogeneous and changing environments.

4.2. Overall platform description

A TraSer network consists of TraSer nodes (i.e., servers in charge of maintaining item-related information in their database) and TraSer clients (which provide interfaces for querying and updating of item-related information by human operators or other hardware/software components). The requirements listed below determine the architecture proposed for the TraSer network.

TraSer focuses on items which are unambiguously marked with an identifier. The latter can be entered into TraSer through a reader unit which is either a specific piece of hardware (RFID/barcode reader, alphanumeric terminal etc.) or software (in the case of product data management). Identifiers are static, they cannot be altered by the system. Data migration from one identifier to another is supported by the system, but the method of re-labeling is out of scope of TraSer.

Data associated with an item (having a given identifier) can be updated or queried through one given node in charge. An administrator is responsible for configuring and maintaining the TraSer node. Although the TraSer project will specify and implement one given software solution for TraSer nodes, other pieces of software may be TraSer-compliant as well, as long as they provide the same services, data and communication interfaces. This is important as some potential industrial customers have already pronounced their preference of re-implementing TraSer components with their own software tools.

TraSer Clients are entities which do not permanently store item-related data and provide no services related to given items but can contact TraSer nodes to use their data and services. The primary purpose of clients is communication with a user who can be either a human operator or a piece of hardware/software. Although we may specify a given range of possible TraSer clients, there are, theoretically, no constraints concerning the innards of a potential client, as it is only the communication behavior which determines its validity as a TraSer client.

It is a general principle that only TraSer nodes and TraSer clients can be directly connected to TraSer nodes. Other components, such as already existing ERP systems, can be linked to TraSer nodes through special clients acting as adapters.

Figure 6 shows possible interactions between the entities listed above-note that the interfaces marked with dotted lines may not necessarily belong to the core specification of TraSer.

4.3. User characteristics

There are two base classes of users of the system, clients and data owners. Servers are only used by data owners, and only through the configuration interface. Clients of the system communicate with the client applications and put a significantly greater load on the system.

Clients are further divided into three sub-classes: checkpoints, partners and analysts. Servers can send and receive messages from other servers, in situations like this they are treated as partners.

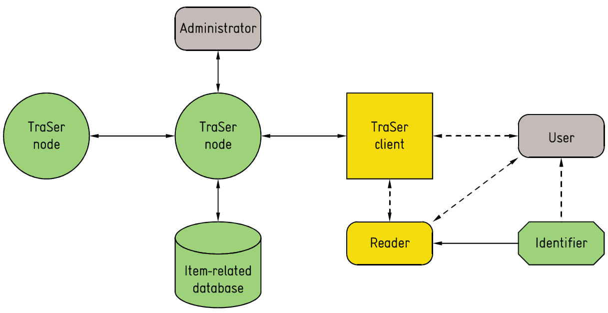

Figure 6: Components and interactions within TraSer

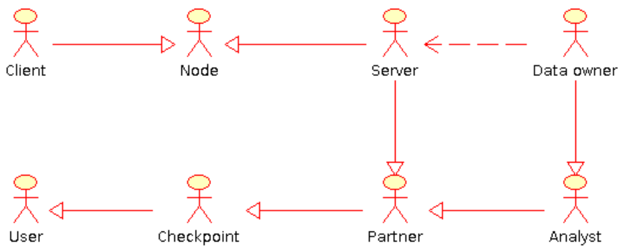

Figure 7: Hierarchy of actors

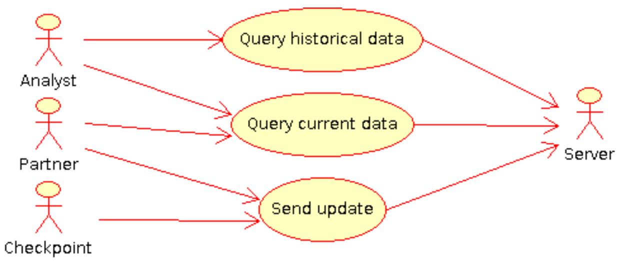

Figure 8: Everyday communication use cases

Checkpoints send update messages, but do not access the information stored. Typical checkpoints comprise logistics providers. Partners both update and query data, but the set of queries typically does not contain complex computations or retrieval of large historical data-sets. Analysts on the other hand have greater access and either use the system as a decision support tool, or want to extract rather old information for tracing purposes.

The TraSer library maintains a catalogue of partners' data. This catalogue is used for creating a secure communication channel over the internet and to know what is the communication and network related capability of remote parties. This catalogue can be used by any implementation using the TraSer library. Server configuration includes the management of authorization rules, supported message types, lifecycle, entity mapping and relaying services. Entity mapping is implemented via numbering scheme translation.

Numbering scheme mapping can be offered as a service on the server. If the server operator (i.e. the data-owner) decides to make the mapping rules available to others, it can be accessed by everyone, most importantly checkpoints that due to the lack of prior knowledge of entities to be handled, have limited possibilities in defining the mapping rules locally. Another service that can be offered by the server is the publishing of change of certain aspects of data regarding specific items, in other words client can subscribe to changes of information. In this case, after the client registers this fact, which is approved by the server, the server sends a notification message every time the data in question changes.

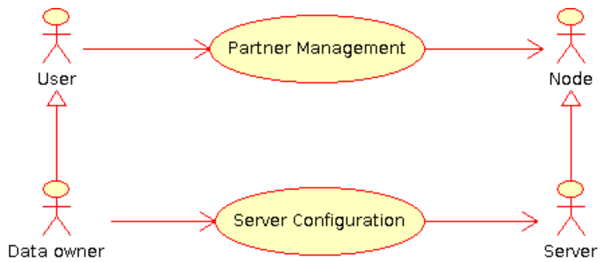

Figure 9: Node management use cases

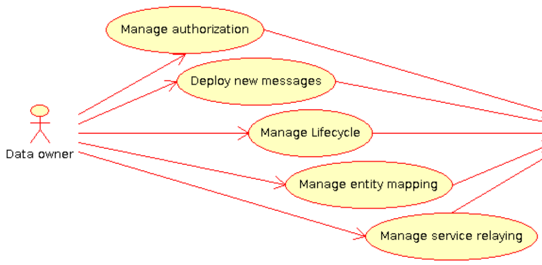

Figure 10: Server management use cases

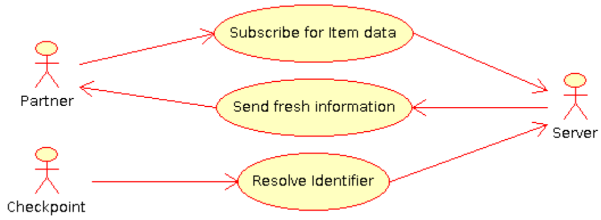

Figure 11: Publish / Subscribe & Identity resolving use cases

4.4. Partner management

In the TraSer platform there are partners and service addresses. Each partner that needs secure communication (i.e. wants to communicate over the internet) possesses a private-public key-pair. This key-pair is used to secure and validate messages if sent over a possibly compromised channel like the internet.

Servers may offer their services using more than one communication channel, where different channels may have different settings. An example would be whether non-secured messages are accepted via a channel or not.

Security keys are in zero-or-one-to-one (0…1-1) correspondence with partners, meaning that partners can only have one security key and exactly one partner is associated with a security key. Service addresses and partners on the other hand are in many-to-one correspondence.

In TraSer users can export the contact detail of a local user that can be later imported into the partner catalogue of other parties. The user can select which service addresses he wants to include in the exported contact details. Of course it is possible to add partners to the catalogue by hand, and users can later modify already added or imported contact details as well as the details of the local user.

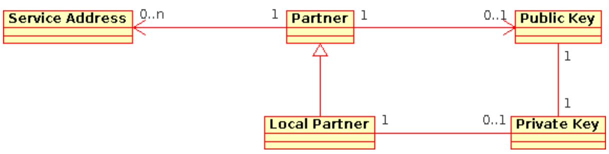

Figure 12: Partner data, class diagram snippet

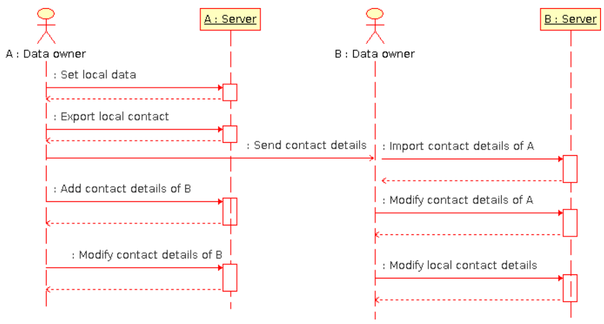

Figure 13: Partner management, sequence diagram

4.5. Interoperation with non-TraSer environments

As not all industrial users obey TraSer principles, an Item identification scheme may be different from ID@URI. E.g. the identification may be represented as a Serial Shipping Container Code (SSCC) instead. In such case a translation must be made to the ID@URI.
For such cases the TraSer architecture offers three options:

- Upload clients may store information on all non TraSer items in a default server with a fixed URI
- Based on certain parameters (e.g. the SSCC prefix or the ISO 15963 allocation class), stored in local client settings, a URI may be chosen by the upload client
- The upload client may access a look-up service, that responds with an URI based on the existing ID plus possible extra characteristics (such as the Item Type)

TraSer will support protocols to use ID@URI look-up services. The URI stored in a client or looked-up through a service needs not be the final URI where the Item information is stored. The update and query traffic may further be redirected based on criteria at the Server node. Such redirection however should be invisible for the clients.

Another special case is when multiple (but different) ID@URIs are affixed to the item, or when an Item label is replaced with one with a different ID@URI. This may be needed when the IDs are pre-allocated to or pre-printed on the label. In this case all URIs should ultimately point or redirect to the URI where the Item information is stored.

4.6. Confidentiality and transfer of information custody

Not everyone is entitled to upload or query information of Items. Each information category of each Item has an owner. The owner decides who may query and who may upload parts of the information belonging to that category. The TraSer concept is however based on an open environment and is jeopardized if upload restrictions are too strict. It should for instance not be necessary for a carrier to register with each of the information owners in order to scan the Items he carries.

Updates of information ownership and user rights are registered as a special kind of event.

Change of information ownership may imply that storage services are transferred to a new Server node. The new owner of the information is also responsible for rendering these services and he may decide to employ another service. It is also possible that the former owner is not authorized any longer to retrieve certain Item related information. Wholesalers for instance sometimes do not wish manufacturers to know who the final customers are. Yet the URI of the first information owner in the chain may be affixed to the Item as a barcode or in an RFID tag.

TraSer therefore includes a redirect mechanism. In case information storage is transferred to a new server, a link will be established on the old server. Information upload and retrieval is not performed directly, first the server is interrogated whether he still holds the applicable information. This mechanism is illustrated in Figure 14. Principles are:

- The identity of clients and nodes should be verified by means of signatures and certificates
- The Uploader is agnostic about information confidentiality requirements, the protocol must always be the same.
- URI transfers may be cached: the second upload or query is directed to the right node immediately
- The types of information should be coded (technical, logistic, usage)
- TraSer does not support:

– The case when downstream parties (e.g. customers) should not know the identity of the URI holder
– The case when manufacturers refuse to transfer ownership (or have bad or illegal intentions)

When a party in the chain drops out without redirecting its URI or without updating the redirects upstream, the chain is broken and information on the Item cannot be retrieved or updated any longer. This problem can not be resolved technically, but should be covered contractually.

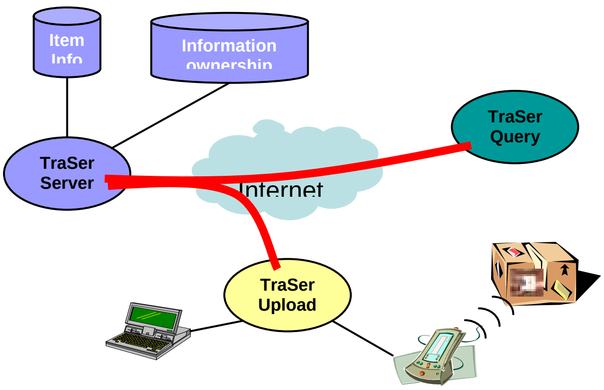

Figure 14: Information Confidentiality

5. CONCLUSIONS

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://www.traser-project.eu) is aimed at overcoming this obstacle by providing an easy-to-maintain open-source solution platform for tracking and tracing applications.

Given the findings about common use and placement of AutoID middleware in the enterprise IT infrastructure, a superficial first look at a TraSer node through clients attached to it may lead to the conclusion that TraSer is middleware in itself, in view of its capabilities of receiving reader input and communicating with already existing higher-level enterprise IT components. However, a closer look at TraSer nodes reveals properties which were, until now, not covered by AutoID middleware, especially i) long-term, organized storage of item-related data and the processing of queries regarding their access, and ii) communication of item-related messages within or across organizational borders. TraSer is, therefore, not meant to be yet another product to compete with today's middleware solutions. Instead, TraSer clients can very well rely on existing middleware, especially when it comes to the aggregated collection of item-related data from autonomous sensor/reader clusters. In later phases of the project, the adoption of solutions like those found in Singularity (Singularity 2005), Blue Vector Systems (Blue Vector Systems 2005) or RFID Anywhere (RFID Anywhere 2006) can be considered for trial implementation. Nevertheless, it has to be carefully assessed whether the practical realization of such experiments should be carried out within the framework of the project or left to the open-source community.

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