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IDENTITY-BASED TRACKING OF PRODUCTS AND PRODUCT DATA IN CHANGING NETWORKS

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Abstract:

The paper addresses a subject of high relevance for small and medium sized enterprises (SMEs) participating in today's changing supply chains. Product-centric application development and using design patterns to link related web-services directly to the electronic identity of products are proposed. To identify and track products the ID@URI identification scheme is advocated. The scheme combines serial numbers and URLs to produce globally unique product identifiers. The TraSer-project aiming at implementing an open-source solution platform for product centric web-services has been started this year. Based on the first phase of the project the paper also outlines differences and advantages of the TraSer-approach compared to other existing approaches.

Keywords:

Supply-chain, track and trace, product and product-data identification

1. INTRODUCTION

In the present business landscape, companies should not be considered independent entities, but parts of multi-echelon networks, such as supply-chains. Material flow transparency, specifically the visibility to inventories and deliveries in the whole supply network, is considered an imperative requirement for successful supply-chain management, and has been associated with significant efficiency and quality improvements ([1], [2], [6], [12], [19]).

The development of innovative customisation, logistics, asset management, and other value added services based on product identity (i.e. tracking) are currently difficult and excessively expensive for SMEs. The problem derives from the need of frequently interrupting and redesigning solutions when joining or leaving an enterprise network, and from the lack of resources for the required redesign.

The paper proposes innovative ICT-enabled tracing and tracking solutions that are adaptable to the specific needs of local and regional SMEs and that support lean organizational networking and process integration.

2. CURRENT STATE-OF-THE-ART

Tracking is a critical challenge to progress towards networked business in a wide range of operations management domains. Resolving the challenge requires a fundamental shift in how operations are perceived and controlled, as well as developing new theory on both operations management and information systems design.

The urgency in doing so is illustrated by the simple fact that tracking products and electronic product representations across enterprise boundaries currently requires substantial manual work, or extensive system-to-system integration work. From an application point of view, tracking functionality is tightly coupled to the systems and practices of the individual network participants, resulting in network level operational processes being rare and expensive. Few SMEs, regardless of their desire for supply-chain efficiency, have implemented supply-chain transparency solutions. Even fewer have developed solutions for transparent product customisation, project delivery and asset management in temporary enterprise networks, such as the networks for building a new office, or production plant, or the networks involved in maintenance and repair.

Five reasons for the low adoption of current transparency solutions by the SMEs can be identified from the literature: (1) *the available options mostly involve high investments*; (2) *presuppose sophisticated internal systems*; (3) *require IT expertise*; (4) *are applicable for communicating only with a single large partner*; and (5) *a lack of trust in terms of how the information will be used* [8]. These reasons will be reviewed next in more detail.

Most current information technology solutions for enabling material flow transparency and collaboration in multi-echelon supply-chains require considerable investments. The motivation for the solutions is that the potential long-term savings offered will outweigh the investment needed for a tighter integration of the supply networks. However, the volume of business transactions between an SME and its business partner often falls short of justifying the IT investments aimed at facilitating that relationship ([18], [15]). Also, the cost of the solutions is simply too high for many SMEs' investment capability [18].

The current supply-chain transparency and collaboration solutions are mainly designed to appeal to significant market segments, without the need for extensive tailoring of the solution, and therefore only acknowledge mainstream enterprise software packages [18]. However, SMEs mainly operate with legacy systems or low-end standard software packages [15], since the more advanced systems are most often too expensive and unnecessarily sophisticated for the needs of SMEs. Therefore, in order to use existing supply-chain transparency and collaboration solutions, SMEs have to abandon the efficiency benefits of integrated systems by operating the solutions manually [15]; or face an additional investment of an internal information system that can support the data sharing system [18]. The need for investment on internal systems invariably makes the total cost prohibitive [18].

SMEs usually have only limited technical expertise and IT resources. In contrast, most transparency approaches demand significant expertise and resources for installation and maintenance. This misfit in the required and actual resources is widely stated as a significant root cause for SMEs lack of investment in supply-chain transparency solutions ([18], [3], [15], [17]). From an SME-viewpoint transparency solutions should consume as little as possible information technology oriented resources, both in implementation and maintenance, enabling the companies to cope without recruiting expensive specialist staff.

SMEs also usually invest in supply-chain data sharing systems due to pressure of their large business partners ([3], [15], [13]). Investing to a specific data sharing system with one-business partner limits the systems flexibility of the SME; and other important partners may have incompatible integration requirements [13]. This leads to potential additional integration investments, and also ties the company to the specific partners and increases the partnership opportunity costs of the company [14]. Thus, a typical SME with several important business partners would require solutions that could be utilized in several relationships.

Being a small partner with limited commercial leverage also contribute to the reluctance of SMEs in investing in improving transparency. From a small party point of view ownership and accessibility of product tracing and tracking data are sensitive issues in terms of how the information is used by larger business partners. The use and dissemination thus need be arranged in contracts for goods delivery, and information services become part of the value-proposition in commercial deals.

To sum up, the technical explanation as to why current systems are too difficult and expensive for SMEs is that:

- Tracking and tracing is currently implemented as a set of bilateral agreements between subsequent contracting parties in a supply-chain – there is as yet no network solution,
- Tracking and tracing solutions exist within companies as part of their internal systems, which creates difficult integrations and prevents superposition at network level.

3. BEYOND THE STATE-OF-THE-ART

The solution proposed in the paper has as its base the linking of electronic identity of products and product representations to identity-specific tracking and related web-services.

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 [7] 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 (www.traser-project.eu). Its scientific objective is to develop through iterative innovation actions an understanding of how network partners could be motivated to participate in supporting network level information services deployed by SMEs, and what are the commercial best practices and technological solutions that facilitate such network level services. The technological objective is to understand how to integrate innovative product-centric solutions with existing transaction processing solutions, and how an open source application development platform can be effectively utilized by individual SMEs to develop network level services.

In the TraSer project an open source platform will be developed 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.

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 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 1 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. Developing the key components in the proposed project within an open source community makes investment requirements for SMEs very low. It is to be noted that the tracking application is determined by the user of logistics services, not by the logistics service provider. The advantage of the proposed TraSer approach is that users can start developing identity-based applications that are independent of the particular service provider. Identity-based applications can also be made available after delivery and over the product life cycle for other uses than tracking.

The service provider can respond to the user defined application more or less automatically depending on how it identifies the shipment, how it links to the application located at ID@URI, and how it responds to a user defined application. From the service provider perspective a major issue in the scenario outlined in Figure 1 is how to establish checkpoints for different users and different identity based applications. In the proposed project the goal is that identity based applications and service provider checkpoints are loosely coupled. The hypothesis is that product centric application architecture facilitates loose coupling between user and service provider in a changing network.

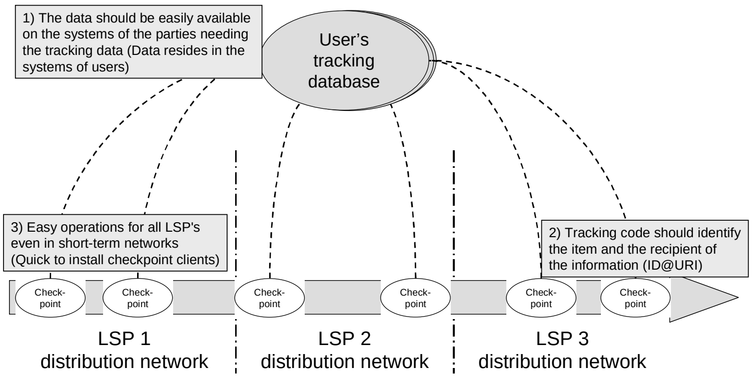

Figure 1: Basic principles of product-centric and independent tracking [9]

4. PATTERN-BASED ARCHITECTURE

The knowledge on how to deploy and develop solutions further is to be documented as design patterns. Design patterns are tested normative theories specifying solutions to particular problem situations. Design patterns were originally developed in object-oriented programming to facilitate loosely coupled program designs.

While this novel approach solves many of the problems current systems are facing, it presents new challenges as well. The project proposes to go beyond the state-of-the-art by developing generic solution proposals that:

- Articulates the design sequence, or 'pattern language', for developing company specific value offerings based on the product-centric approach for tracking in changing network environments,

- Describes how to link product representation and tracking of physical and virtual composite objects across organisations,
- Propose business scenarios that make it easier for SMEs to see how they can offer embedded information services to business customers and consumers,
- Identify the design patterns that support the innovation of new types of service business for SMEs.

Identifying a 'pattern language' of increasing sophistication based on forwarder independent tracking is important to achieve the goal of open and evolvable services. By building on tested design patterns from object-oriented programming (OOP) loosely coupled services can more easily be developed for logistics services on the network level. The basis for a successful adaptation is the conceptual similarity of product individuals tracked by a product-centric application, and software objects in OOP. Figure 2 illustrates the basis for the analogy.

OOP concept	Product centric concept
Object	Internet-accessible software components
Object reference	ID@URI, EPC or similar
Method	Message
Interface	Interface defining messages and message formats
Object container	Database table for object relations

Figure 2: Conceptual analogy between OOP and product-centric tracking [5]

There are two basic schemes to describe value adding operations and allocate them to service providers. These are the procedural-based workflow and the loosely coupled object schemes.

The concepts of object and class from object-oriented programming correspond to entities involved in loosely-coupled manufacturing and service operations design: an object is an individual product item, supplier, employee, customer etc. that constitutes a part of the economic network. From the point of view of designing loosely coupled virtual enterprise operations the most important is the individual product. It is manufacturing, delivering, and servicing individual products that tie together the economic network. The class corresponds to the types of objects in the economic network, i.e. product, supplier, consumer. Individual objects are linked by globally unique object references. At its simplest the object reference is an ID@URI pointer to a product specific entry in a company database.

Product-centric control for a customized product is illustrated in Figure 3. Instead of describing material and information flows, the description focuses on the product individual and its service requirements. Actors are not individually specified, only classes of service providers. The arrows originating at the product individual and facing different supply chain phases represent the service requirements the product individual calls upon and the information it offers. The arrows pointing from different supply chain phases to the product individual represent the different logistics services the supply chain phases provide to the product individual.

The progression of a product individual through its life-cycle can now be described in detail demonstrating how the concept of inside-out control is the basis for a simpler and conceptually more powerful process description.

The product individual is created when it is designed, and the designer/contractor specifies the product model and other descriptions of the product individual. The contractor may also allocate delivery tasks to specific producers through a project plan that is part of the description of the product individual. The product individual and its components can also be given a unique identity.

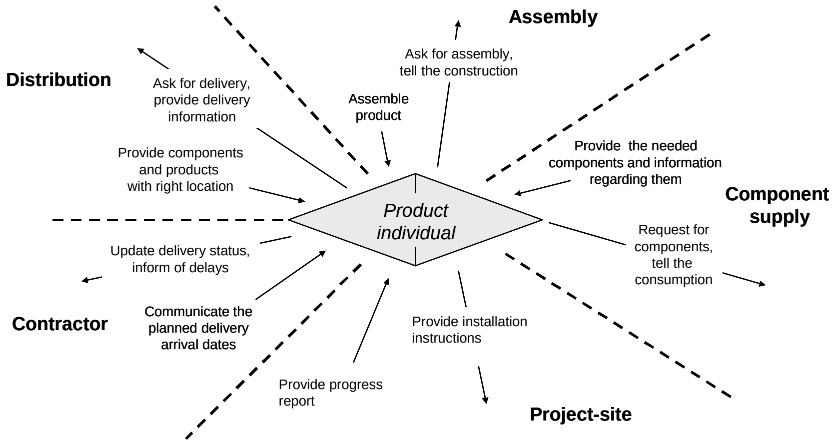

Figure 3: Product centric description of customized product delivery [11]

In a product centric process description every product individual and component may be given its own globally unique identification code. This identification code is the key to connect the product individual to information about it.

When a customized product is produced and delivered, the interaction between the product individual and the main contractor of the product is very important. The contractor sets the tempo for the delivery of the product individual by defining the delivery schedules linked to the product individual. Component producers access service requests and required specifications using the product individual's identity code. Component producers also append the information concerning the product individual to the information regarding the components.

Information concerning the handling can be specified in the product-centric description. The important point here is that this way of describing the process significantly eases the outsourcing of tasks. As the information needed for handling is linked to the product individual, different assembly service providers can be more flexibly used. The control of the delivery is not defined through transactions that organizations exchange, instead, it is controlled by information that is tied to the product individual and accumulated across organizations.

The requirement to implement a product centric process description in practice is that potential service providers need to possess a detector, network connections, and eligible equipment to provide service, in order to handle the delivery as required. Furthermore, the information regarding the product individuals need to be centralized to the product individual itself, not to a specific organization.

5. THE OPEN-SOURCE SOFTWARE PLATFORM

The goal of the current development launched in 2006 in the TraSer project is to develop the solution platform in a direction that facilitates SME development and adoption of tracking based services.

The basic TraSer-solution includes an elementary connection to backend systems because it can be used in a non-proprietary way through SQL (Structured Query Language). The software components are programmed in Java, so communication with databases is performed using the JDBC (Java Database Connectivity) protocol. All registered nodes can be given access to the database connection so they can create and modify their own database tables. Nodes may also use other databases or connections to ERP (Enterprise Resource Planning) APIs if needed in addition to the basic product centric database.

For now, databases seem to be the most practical and universal way to communicate with most existing business applications such as ERP systems. A tighter integration with ERP systems could be achieved by using their proprietary APIs, which would however be tedious due to different programming language interfaces, method interfaces, design philosophies etc. The increasing support for Web Service interfaces to ERP systems could greatly simplify this task, especially for software such as TraSer that already uses Web Service technology. A more direct integration with ERP systems could be necessary e.g. for real-time applications with short reaction times, but for most applications this might not be necessary.

6. INTEROPERABILITY WITH RELATED INFORMATION SYSTEM INITIATIVES

The main current standardization effort related to TraSer's problem domain is the EPCglobal initiative. EPCglobal [4] is mainly focusing on using RFID technology for improving visibility in SCM operations. Visibility in SCM operations has a close connection with the tracking scenarios in TraSer but there are also some major differences between the objectives of EPCglobal and TraSer. The standardization efforts of EPCglobal could be grouped into the following areas:

- RFID technology (e.g. radio communication),
- Item identification (the EPC: Electronic Product Code),
- Object Name Service (ONS) for retrieving Internet addresses where information of the product item can be accessed/updated,
- EPC Information System (EPCIS) for the requesting/updating information about product item(s),
- PML (Product Markup Language) for describing product-related information in a standardized way.

An advantage of the EPC code is that it should be globally unique for any product item in the world (even though there is no guarantee against copying the code and using it for some other product item, which is also true for most other identification codes). The global uniqueness makes the EPC code interesting also for use as the ID part in ID@URI. When using an ID@URI identification (especially if the URI is an URL), there is no need for an ONS. But because the EPC code is too compact for including a URI part, there needs to be some way of retrieving that address based on the EPC code. ONS is an extension of the existing DNS (Domain Name Service), which signifies that ONS information can be added to existing DNS systems through so-called NAPTR (Naming Authority Pointer) records [16]. The ONS approach can also be used in TraSer when the URI part is not available. However, there are some major obstacles for doing so at the moment:

- No largely-deployed ONS infrastructure exists yet,
- Creation, access to and use of NAPTR records is not yet supported by common-place software,
- ONS is a hierarchical system with 'root' servers. The only current 'root' server is managed by VeriSign, and registering appears to be relatively expensive, especially for organizations with limited resources such as SMEs..

7. CONCLUSIONS

At this stage of the research effort it appears that the TraSer approach is in no way in conflict with ongoing standardization efforts such as EPC. On the contrary, the more EPCglobal standards evolve, the easier it should become to propagate TraSer solutions in business. Still, there are also some major differences between EPCglobal and TraSer, which are mainly related to their background and motivations. Such differences are e.g.:

- TraSer is product life cycle-oriented, not only supply chain-oriented,
- TraSer is developing light-weight solutions that can also be developed and used by SMEs and individual end-users of products, while EPCglobal is driven by the needs and capacities of WalMart and similar multi-national giants,
- TraSer is developing solutions for loosely-coupled and temporary networks of organizations, while EPCglobal seems to be focused more towards permanent collaboration networks or networks with one dominating organization.
- TraSer is not 'limiting' itself to RFID technology; it also targets low-end solutions, e.g. barcodes, as well as high-end solutions, e.g. embedded computing devices like on-board controllers in vehicles. The different implications from this are e.g.:
  - Low-end: it can be difficult to put an EPC code e.g into barcodes, and how to do so is not standardized so far,

- High-end: computing devices do not need ONS for establishing connections with backend systems; they can store and maintain the URIs themselves or use other kinds of lookup mechanisms.

In the best case, these differences in background and motivations have an enriching effect both for EPCglobal and TraSer. The only clear 'competitive' effect comes from the fact that if ID@URI or similar approaches could make the ONS superfluous. Then VeriSign and similar service provider companies will lose their pivotal business position, while end-user companies could save money and effort. This could be vital especially for the competitiveness of European SMEs.

Much work also remains to specify the specific design patterns and how they are most effectively deployed, what specific product related services are profitable, and how network partners can be motivated to participate. A major risk of the proposed approach is the implementation of temporary checkpoints in temporary product-centric networks. For the approach to be successful logistics service providers and other handlers' will have to be able to install a number of functionally similar checkpoint clients, or implement a solution where the checkpoint client can be installed temporarily based on information embedded in the product or parcel. The practical requirements for logistics service providers and other handlers to participate in a temporary product-centric tracking network have to be tested in a high volume production environment.

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