TRACKING AND TRACING PARCELS USING A DISTRIBUTED COMPUTING APPROACH

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ABSTRACT

When managing a supply chain or an assembly site there is a demand both for the supplier and the customer to know exactly where along the transportation route the deliverables are.

Some companies offer tracking systems for the whole supply chain, from source to destination. These types of solutions require a centralized server where the tracking data is gathered. The server is maintained by a service-provider, which usually is neither the supplier nor the customer of the product. The introduction of a third party in the supply chain could result in delays or failure in data integrity during the delivery process.

In our paper we propose a lightweight distributed system that allows for automatic notification of a parcel's movements directly to the server of the "owner" of the parcel (usually the sender or receiver of the parcel), without the need of a third party service provider. The concept allows for efficient tracking and dynamic management of the product throughout the whole transportation process.

The Java programming language provides tools for making small, distributed software applications. The software presented in the paper tackles these logistics problems by opening a direct connection between the tracking-checkpoint and the server of the parcel's owner. In this manner the owner of the parcel gets rapidly updated about the shipment's whereabouts. If the owner is alarmed from the checkpoint he can notify appropriate members of the supply chain of the error at an early stage, thus making the whole delivery process more reliable.

The key to our system lies in coding the server location in an RFID-tag or a bar code on the deliverable itself.

1. INTRODUCTION

The complexity of the supply chains in global industry has meant an increasing interest in improving their manageability (Artto et al., 1998). Parts and materials are sought after all over the world and the supply chain is living all the time; business partners come and go (Christopher, 1998).

With requirements of product life cycle management becoming stricter (EU On-Line, 1999) and maintenance becoming more complex due to the diversity of product variants (Bowersox et al., 2000) together with the necessity to improve on product traceability (Töyrylä, 1999), a lot of information about the items is needed. The information should be promptly available on the Internet.

Perhaps the most important information that should be available on-line is tracking data. This is especially important in the project industry where materials have to be on the site at the time required; if deliveries are lost or delayed without the managers being informed, the project may suffer major setbacks (Kärkkäinen at al., 2001).

The members of a supply chain are in many cases independent companies that concurrently participate in multiple supply chains. Building a network for information sharing or a tracking network is therefore a complicated task. Furthermore, allowing an external party to manage the tracking information can be difficult to accept for some companies (Euwe and Wortmann, 1998).

Collaborative information gathering and sharing, where all participants can decide themselves what information they want to share and with whom, could be a solution for many of the aforementioned problems. Using a peer-to-peer type of connection to link the members of the chain and transferring the data directly between the parties also removes the need for a third party server.

The aim of the Dialog project at the Helsinki University of Technology is to create a lightweight distributed system for information sharing by using peer-to-peer connections for product tracking. The method is founded on data stored in an RFID tag. The data consists of an identification number and a network address for each item that shall be traced.

2. BACKGROUND

The need for tracking and tracing items along the supply chain has been long since recognised and logistic companies have therefore set out to offer tracking and data gathering services to solve the problem. The academic communities along with standardisation organisations are also actively taking part in efforts to create global identification methods for items. The standards developed mainly concern identification of items and as such, do not directly define any connection to product tracking systems.

2.1. Proprietary solutions - the centralized approach

Companies such as Savi Technologies that have their business focus set on developing supply chain management systems on a global scale, usually build their systems around one server which functions as a central storage vault for all of the tracking data. (Savi, 2002).

This centralised approach to item tracking can result in rather proprietary solutions often meaning that the companies only can track shipments that are managed by themselves. On the other hand, involving a third party in the data gathering process could also be considered a risk, not all companies are keen on allowing another company to handle their data.

Larger scale companies that have built a tracking system of their own usually have a similar approach, with the same problems (Coia, 2001; Booker, 1999). For instance they may not be able to share their information with their partners without restructuring the data to suite the individual formats and needs of each. In general the companies co-operating in the logistics chain must agree on certain pre-meditated means by which they exchange information. This makes the system inflexible for changes and expansion.

2.2. Product identification standards

The European Article Numbering Association (EAN) is one of the major standardisation organisations that develop item identification methods. Its identification numbering system Global Trade Identification Number (GTIN) is in use in most parts of the world. The Auto-ID centre at Massachusetts Institute of Technology is working on a global method of identification an Electronic Product Code (EPC).

2.2.1. Global Trade Identification Number

EAN and its North-American counterpart: the Unified Code Council (UCC) has created the Global Trade Identification Number (GTIN), which is printed as a barcode on the product and identifies the manufacturer of the product together with an identification number. The GTIN codes are in use all over the world, although North-American codes are not compatible with the codes in other parts of the world. (EAN Int., 2001)

2.2.2. Electronic Product Code of the Auto-ID centre

The very interesting research by the Auto-ID centre at MIT has also been an interesting reference for us. Whereas the Auto-ID centre is developing a scheme for a larger scale identification system, an ‘Internet of things’, we have chosen a less ambitious goal to identifying the object of interest (Brock, 2001).

Instead of using large numbers to create the code that uniquely identifies the item, we only store information about the location where further data about it can be found. This leaves the choice of what data to share and with whom to the maintainer of the product database.

2.3. Product identification technologies

Different identification technologies that allow for automated identification exist but none of them is totally superior to the other at the moment; longer reading distance and easier reading correlate well with the price. The technology most frequently used today is barcodes, but Radio Frequency Identification (RFID) tags have gained popularity as they have become more affordable.

2.3.1. Barcodes

Barcodes are by far the most common way of tagging parcels and their advantages are undisputable, they are inexpensive and the reading distance is reasonably good. The disadvantage of barcode technology is mostly related to wear and tear, the labels can become unreadable when subjected to harsh handling environments.

We use barcodes mainly to store a backup copy of information written into the RFID tag. Although there is a multitude of different barcode formats to choose from, we have decided to use CODE 128 because of its ability to store the full range of ASCII-characters. CODE 128 also allows for longer strings of characters that might be necessary if the address become complicated.

2.3.2. RFID technology

Radio Frequency Identification is based on wireless communication in radio frequencies. The system consists of a reader and a tag that reacts to the electromagnetic field or impulse that the reader emits. Every tag can contain a limited amount of user defined data. The data is stored in a chip that is powered by an inductive loop or a small battery. The reading distances for a tag can be anything up to a 100 meters depending on the type of tag. (ISO/IEC, 2000)

Cost, reading distance and the amount of data stored are the main parameters that have to be considered when choosing the type of RFID technology to use. Our system is not limited to a specific type of tag however, the usability of a certain RFID technology is only limited by the amount of data that can be stored in the tag; the data structure we use must obviously fit into the available memory.

3. THE DIALOG CONCEPT

Having considered the current practices in product data management and product tracking we set out to develop a different system that would make it possible to have tracking information readily available to whoever is authorized to view it, whenever and wherever it is needed the most.

In our project we abandon the centralized model and concentrate our efforts on developing a distributed, peer-to-peer type of information sharing. We equip the parcel with a tag that contains information about where on the network additional data about the package can be found. When the parcel with the tag passes a checkpoint, an automatic location update together with the checkpoint reading time is entered in the package initiator's database tables. The event has thus automatically been logged.

The real advantage of the concept is that the owner of the checkpoint is insignificant, the checkpoint does not segregate the parcels passing through it. Whoever owns the parcel receives an automatic location update in the company database. Spanning the tracking over multiple companies and sharing the tracking responsibility in this way becomes feasible with P2P technology. Using this type of flexible information sharing means that alerts of mishaps and delays can swiftly be conveyed to those concerned and appropriate action can be taken.

3.1. Giving the product an identity

The address stored in the tag with the package has the following structure: ***id@uri***, where the *id* is a constant identifier with local scope making sense only to the company specified in the Unified Resource Identifier *(URI)* (Främling, 2002). It is possible to add other information to the address, concerning the services like protocol specification, port number and a directory tree.

A typical example of the address structure could be as follows: 5005744@dialog.hut.fi:1099. Here the number 5005744 is the internal reference identifying the shipment. The address dialog.hut.fi directs the client software to a server, where the software is listening for connections on port number 1099 (the port number is optional, usually the default value is sufficient).

We store the whole string in an RFID-tag attached to the parcel together with a backup copy of the same string printed as a barcode on the package list.

Identification number	@	Unified Resource Identifier (URI)	:	Port number
5005744	@	dialog.hut.fi	:	1099

Table 1: In the first section we store the identification number followed by a URI, which is separated with an @-sign; at the end there is the port number added to the URI.

3.2. Distributed approach

The peer-to-peer concept as such is rather new. Probably Napster is the most famous and first to use peer-to-peer concept in file transfer. It was followed by Gnutella, Kazaa and the likes; programs built to use the peer-to-peer paradigm as their way of data sharing and communication.

Two companies should not need to involve a third-party in order to share information without a real service value in the intercommunication process. Therefore, the main objective of the *Dialog project* at Helsinki University of Technology (http://dialog.hut.fi/dialog) is a lightweight, collaborative tracking system that should avoid dependency on centralised proprietary servers. A peer-to- peer (P2P) system with the following benefits:

1. **No centralised database or planning procedure necessary**. This means that new logistics service providers could readily be integrated into the architecture by updating the routing tables of the logistics network it connects to.

2. **Complex centralised optimisation algorithms would be replaced by simple, localised computations**. Moreover, dynamic changes or disturbances in the state of the logistics network could be taken rapidly into account.

3. **New service providers can dynamically plug-in into the logistics services once standardised service interfaces and software components have been developed**. Standardised software components would signify simple set-up of new services, which would make these systems interesting also for smaller companies, who do not have the capability to develop their own system from scratch.

4. **Standardised P2P communication means that existing collaboration and delivery networks between companies could be easily modified.** It would no longer be possible for a big company to tie up their subcontractors and force them to use only the company's own information systems.

4. SOFTWARE ARCHITECTURE

The minimal Dialog software configuration consists of one client and a server. The clients control the reading devices and send tracking data to the appropriate server. The servers then communicate with each other in order to enable tracking data sharing and if necessary send warnings, damage reports, etc to one another. Other information, such as maintenance and disposal data, could also be shared using the same method

4.1. Checkpoints and server

At the checkpoint we use a client computer that is connected to the tag-reading device. The reader acts as a terminal that communicates via radio with the base-station connected to the client computer.

In Figure 1 we have an example of how the parcel's (1) movements are tracked. When the parcel's tag is read at the checkpoint (2), the client computer connects to the web address stored as an URI in the tag (3). The client communicates with the server of the parcel's owner (4) using Java's Remote Method Invocation (RMI) protocol. Then the server updates the location directly to the internal company database (5) using Java DataBase Connectivity (JDBC) (Sun Microsystems, 2002).

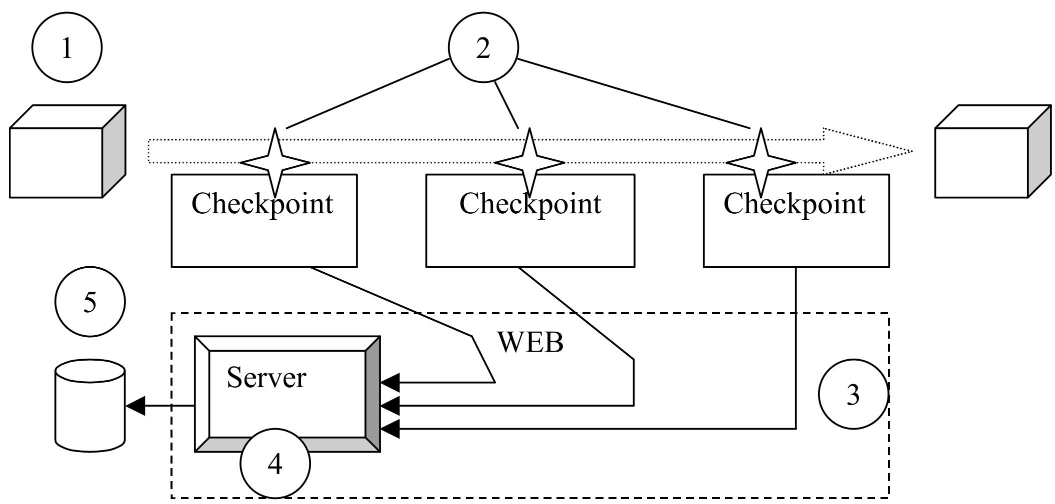

Figure 1: The parcel (1) moves through its transport route and is registered at the checkpoints (2), which then form a peer-to-peer connection using the address on the parcel via the web (3) to the server (4) of the parcel's owner, where the checkpoint data is entered into the database (5).

4.2. JAVA and RMI

The Java programming language developed by Sun Microsystems has been defined with network programming in mind from the very beginning. The programs run in a Java Virtual Machine (JVM) that interprets the application and converts the commands to those natively used by the computer. This means that all programs work more or less the same in all operating systems and environments that have an implementation of the JVM.

Remote Method Invocation (RMI) (Sun Microsystems, 1998) is one of the features in Java that simplifies distributed computing. With RMI one can easily develop an object-oriented program that can share its objects along with their methods with a remote computer. In contrast, other distributed systems available usually permit only attribute transport between client and server.

Sun is also developing two other new mobile network computing schemes based on Java and experiences gained from RMI: Jini and Jxta. Jini is used for creating a general short-range mobile network and Jxta is aimed to make the developing of peer-to-peer systems easier. Both technologies are, however, still under development.

5. SWOT ANALYSIS

The Dialog project started in the autumn of 2001, one of the goals was to prove the design concept in an actual environment. A suitable industry partner was found and the system is therefore currently in beta testing at the partner site in Finland. We use a rudimentary setup with only two checkpoints, one at the packaging central at the sender end and the other at a reception point close to the construction site. At the time of writing this article we are closing in on the deadline of production use of the test system and things are looking promising.

5.1. Strengths

The system automates checkpoint information handling and thus reduces human error. The personnel still has to make sure that all parcels going through the checkpoints are registered and that their tags are read, but nothing needs to be typed. Checkpoint information is automatically logged with the right party.

Reporting damages is made as simple as possible. When damage is noticed, only the quality of it has to be typed in. The damage report is sent to right parties automatically just by reading the tag of the damaged part.

The system improves product data management and offers new possibilities for life cycle management. Product data can be made accessible for specifically trusted parties. Other kinds of information such as maintenance and disposal information can also be made available in the same way.

Installation and configuration of both the client and server programs is easy. The server should install in less than an hour; the client side installation is even faster. Both systems require configuration only when they are started the first time.

5.2. Weaknesses

The Dialog project is university driven, with limited resources. Consequently there is a risk that the technology will not become widely enough adopted in the industry for it to become a real option for tracking or information sharing.

5.3. Opportunities

Since our research project is university based without direct economical profit as the main objective, we aim instead to create an open standard that anybody could implement. A wide adaptation of the technology could be a feasible opportunity.

5.4. Threats

Software patents are nowadays used more to prevent others from using a certain technology than actually protecting innovations. Whenever there is a need for some sort of standardisation, they might present a threat.

As companies become more aware of the security hazards in using the Internet as a data transfer medium they are less and less willing to open new ports in their firewalls; every new hole means a new risk.

6. CONCLUSIONS

The Dialog system proposes a universal encoding scheme that makes it possible to create a link between physical objects and the information and services concerning them. One main advantage of the system is that it uses existing coding standards and can therefore be put into use immediately. Current pilot installations for the tracking and tracing of items provide the necessary proof-of-concept of the system and of the technologies being used.

The fact that the Dialog system is usable for connecting any physical object to its "virtual counterpart" signifies that user instructions, maintenance records and other information can be directly accessible just by reading the identifier tag. This approach could also be well suited for product life-cycle management, where information about any physical object remains tightly connected to it all the way from its conception to when it is finally destroyed or recycled.

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