INTERMODAL END-TO-END TRACKING AND TRACING - INTRODUCING THE PARCELCALL APPROACH*

K. Jakobs[1], A. Busboom[2], C. Pils[1], M. Wallbaum[1]

[1] Technical University of Aachen; CoSc Dept; Informatik IV; Ahornstr. 55; D-52074 Aachen; Germany.
Tel. +49-241-8021405; Fax +49-241-8888220; e-mail: Kai.Jakobs@i4.informatik.rwth-aachen.de.

[2] Ericsson Eurolab Germany; Ericsson Allee 1; D-52134 Herzogenrath; Germany.
Tel. +49-2407-5757813; Fax +49-2407-575400; e-mail: Axel.Busboom@eed.ericsson.se

SUMMARY

The ParcelCall project will realise an intelligent end-to-end tracking and tracing solution across all borders of carrier and transportation modes. It will draw on emerging technologies, e. g., radio frequency identification, and public data communication networks to develop the system and verify the application in a realistic business context. A variety of end systems, including standard mobile phones, may be used to obtain near accurate tracing and status information along the complete logistic chain.

MOTIVATION

Three general observations underlie the work described here:

- Europe has a very dense road network, a modern rail network and an air network that covers the entire continent.
- Europe also has very advanced communication networks, consisting of dense, high-quality fixed networks, satellite coverage, and wireless communication networks, such as GSM and – in the near future – GPRS (General Packet Radio Service) and UMTS (Universal Mobile Telecommunication System).
- Transport and logistics today have evolved into a high-technology industry.

Unique opportunities will be generated once the transport and the communication infrastructures are integrated.

* This work was partly supported by the Commission of the European Community (CEC) as part of the IST ParcelCall project IST-1999-10700 (www.parcelcall.com).

BACKGROUND AND GOALS

Distribution is no longer about moving cargo over road or via air from A to B, but is a complex process based on intelligent systems for sorting, planning, routing, and consolidation that supports faster transportation, different transportation modes, fallback scenarios in case of failures, value added services such as time sensitive deliveries and tracing of products throughout the supply chain or transport network. Many large logistics companies have developed solutions for delivering these services in order to meet the requirements of their customers and to improve their services.

Whereas larger companies have developed solutions for delivering these services in order to meet the requirements of their customers and to improve their services. Smaller companies, however, cannot afford these investments and are mainly active in the "old" point-to-point transportation market, or co-operate with the larger companies, using their respective systems.

The companies that have the necessary information systems in place to participate in the market for high-end transport solutions, normally offer their customers methods for tracing their consignments. Even though many customers would benefit from using this information in their own information systems, only few of them are doing this today because of the large investments in their systems required to adapt to the proprietary interfaces of the transport companies. However, these systems typically have two major drawbacks:

- They do not normally work across company boundaries.
- They do not provide accurate 'life' information about location and, particularly, the status of individual units or items.

Continuous information about the current position or status of transport goods (in the sense that the exact geographic position can be queried at any time) at item level is not commonly available today. Typically, this information is provided – if at all – at a vehicle or container level only. Existing tracking solutions are typically based on scanning bar codes at process or control points. Furthermore, very few companies have true global or even European coverage. In daily business, products are frequently shipped by subcontractors of the transport company. If the subcontractor does not provide a point-to-point service, tracing is no longer possible. Only in a few cases do carriers exchange tracing information, but in most cases the costs for adapting the proprietary systems to each other are prohibitive.

The key idea of the ParcelCall project is to provide relevant services on top of open and standardised communication protocols, potentially including e.g., GPRS, ISDN, GSM/UMTS, and TCP/IP. Easy adaptation of legacy systems, operated by the individual carriers, to the new information infrastructure will be another key design criterion. Seamless interoperation between these systems on the one hand and the new tracking & tracing system has to be guaranteed.

THE ENVIRONMENT AND THE ARCHITECTURE

The ParcelCall project will develop a new, unified information and communication plane (see Fig. 1), thus enabling seamless tracking and tracing across different operators and across different transport modes. The key idea is to provide common open, standardised interfaces between all system components.

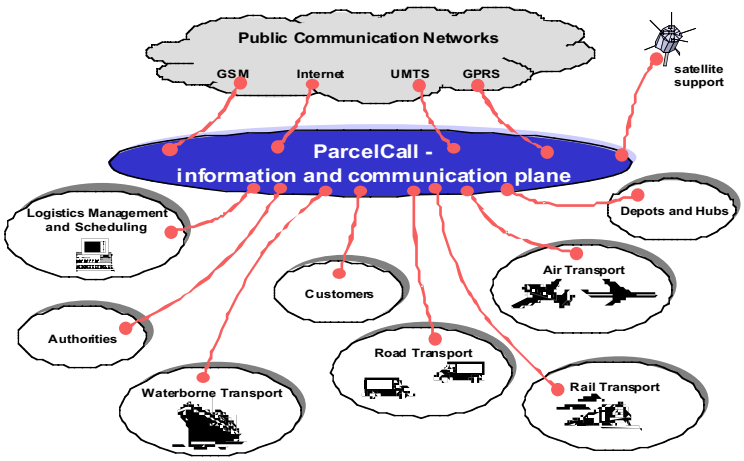

Figure 1: The ParcelCall Environment

The overall ParcelCall system architecture is shown in Fig. 2. There are some key requirements on the design of an open tracking and tracing system. These include:

- inexpensive,
- simple to implement and easy to maintain,
- easily accessible (via e.g., the Internet, ISDN, and cellular networks),
- scalable,
- reliable and secure,

and that it provides global end-to-end tracking and tracing functionality across company boundaries and irrespective of transport mode(s).

Information on individual items, including position and status, are collected by a Mobile Logistics Server (MLS) located on board a vehicle. The former type of information is obtained via the Global Positioning System (GPS), 'intelligent' tags are utilised to collect the latter.

These Thinking Tags, which will also be developed by the project, will form ad-hoc networks that can be applied to self-adapting hierarchical packing schemes or to active status monitoring of critical freight contents. Alarm messages will be actively generated if, e. g., an item enters a critical state (temperature, humidity, pressure, acceleration, etc.). It is also conceivable that in-vehicle shelves themselves are equipped with intelligent devices, such that the fine-scale location of an object within a vehicle can be determined.

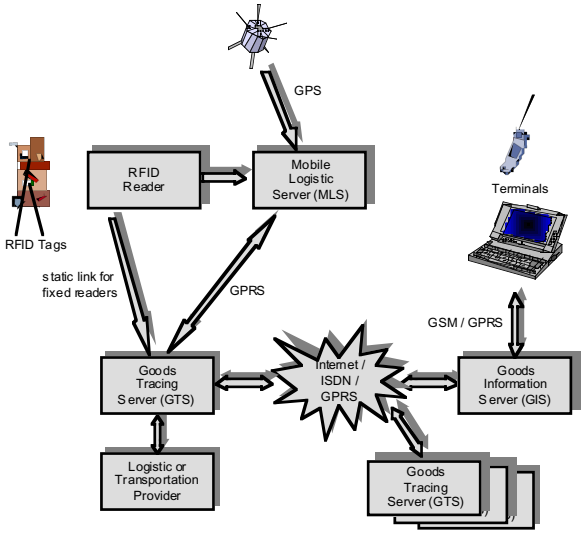

Figure 2: The ParcelCall Architecture

The MLS sends the compiled information to a Goods Tracing Server (GTS). Every participating delivery company needs to install at least one GTS, which also serves as the interface between the respective internal IT system and the ParcelCall service. Thus, the set of GTSs forms a highly distributed data base holding the information available to all end-users. The individual servers are interconnected via public networks (as e.g. the Internet, ISDN or GSM/GPRS). It should be noted that even very small companies which do not have their own tracking and tracing system can utilise the ParcelCall service, as a GTS (typically a PC) is pretty much the only additional piece of hard- and software required.

Passive and Active Tags

Passive RFID tags are available today at moderate costs, and can be easily integrated into labels with printed and bar code information. Due to the costs (compared with simple printed tags) and infrastructure requirements (printers, readers), this technology has yet to gain widespread acceptance for tagging of short life-cycle products and low value transactions. However, it is only a matter of a few years before it reaches the retail sector and gathers the momentum necessary to play an active role in global markets. Static RFID tags – with limited data capacity and read-only access – can already be printed using standard printers with special ink, without the need of integrating any hardware (chips). RFID tags with read/write capability and a capacity of a few hundred bytes are available as low-cost one-chip solutions. Complementing 1-D and 2-D bar code labels by RFID tags, i. e., passive transponders with limited functionality and data capacity, will enable automatic identification upon transhipping, without the need for manually handling the consignments and scanning the labels. As a further innovative step, ParcelCall will explore the technological issues of active "Thinking Tags" instead of passive RFID tags. These Thinking Tags, developed by the project, will combine active short-range communication capabilities with sensing, memory, and computing power. Key issues in their design will be low power consumption and low costs.

Thinking Tags will offer opportunities far beyond the mere transmission of static identification information, such as:

- continuous measuring and monitoring of environment conditions (temperature, humidity) for sensitive shipments (e. g., food) at the level of individual pieces,
- active alerting of the owner of a shipment in case of an alarm, i. e., deviation from the planned transport route, inadequate environment conditions, etc.,
- recording of the history (location, environment conditions, status) of a shipment in order to provide evidence in liability issues (e. g., for security transports). Subsequently, we assume that each transport good has a Thinking Tag.

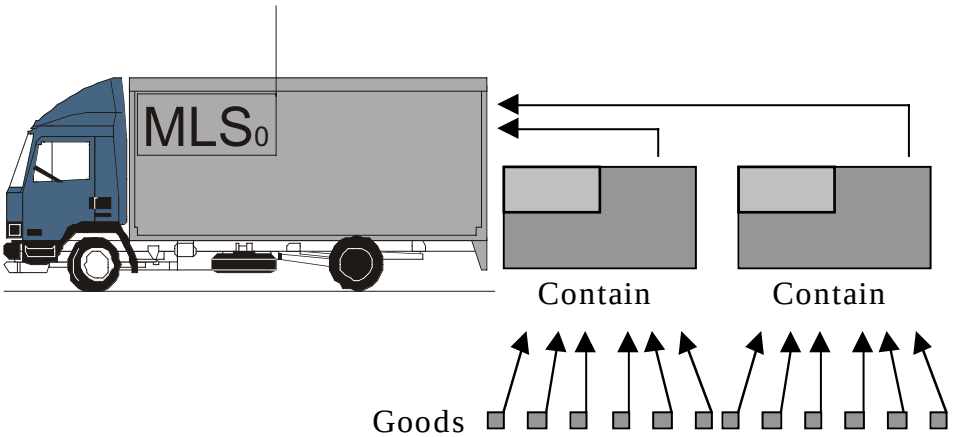

Figure 3: The MLS Hierarchy

The Mobile Logistic Server

Each transport unit has a Mobile Logistic Server (MLS) which keeps track of the goods within that unit. As mentioned transport units are for instance trucks, freight wagons, and containers. Containers contain transport goods or other containers, thus building up a tree hierarchy of transport units. Since each container might have a MLS, the transport unit hierarchy causes a MLS hierarchy as depicted in figure 2. Except for the top level MLS (root of the hierarchy tree) all MLSs communicate with their father MLS and their sons.

Implementing this hierarchy tree has several advantages: First, as the this hierarchy corresponds to the carriers delivery plan the hierarchy approach allows validating the carrier's plan. Second, in general communication peers are very close to each other (less than 10m range). Thus, the hierarchy approach allows for short range communication.

From a MLS's point of view there is no difference between a tag or an MLS. In the remainder we call goods and transport units within a container just items. A plain MLS must only implement an item interface. Only a top level MLS must implement an item interface as well as a Goods Tracing Server (GTS) interface.

Among others, intelligent tags and MLSs store a unique identifier, the item's destination address, and constraints related to e.g. temperature, shocks, or humidity. If a threshold of one of the item's constraints is exceeded an event will be generated and passed to an MLS superior within the hierarchy. The latter forwards the event to the responsible GTS. Finally, the GTS forwards the event to the carrier's IT system (which may or may not react to the event) or a Goods Information Server (GIS). If a transport unit within this message chain has a control system (e.g., the control system of a refrigeration unit), this control system can register with its associated MLS to receive events. Thus, transport units can also react to certain events. This is of crucial importance as a transport unit, for instance a vehicle, might be disconnected from the carrier's IT system and cannot anymore receive instructions. Moreover, only the transport unit's control system can take appropriate actions in response to certain events.

Loading of transport units changes the MLS hierarchy. To keep track of hierarchy changes items are scanned while being loaded. As the carrier's IT system plans the loading process in advance the ParcelCall system can check the loading procedure while scanning the items. Therefore, each MLS receives a list of contents from a GTS in advance of the loading procedure. While the items are scanned the MLS checks whether the item belongs to the received list or not. If an item is loaded which is not in the list of contents the local MLS sends an alarm message to the control system of the transport unit. When the loading procedure is finished the MLS notifies the responsible GTS that the loading procedure has been completed successfully.

The Goods Tracing Server

Goods Tracing Servers (GTS) are interconnected to a carrier's intranet. The GTS network forms the backbone of the ParcelCall system as it interconnects and integrates the individual ParcelCall servers on the one hand, and the carrier's IT system on the other. A GTS comprises of two databases: a Home Database and a Transitory database. The Home Database contains item information, e.g. the item's current position, its expected time of delivery, etc. The Transitory database holds MLS hierarchies.

<u>The Home Database</u>

As it is required that the ParcelCall system must scale it is impossible to store information of each item within each Home Database. A GTS is responsible for a fixed number of top level MLSs (top level MLS cannot move). When an item enters the ParcelCall system for the first time it must be either registered at the GTS or at a MLS. The MLS forwards registration information to its responsible GTS. The GTS stores the item status information and the identification of the responsible top level MLS in its Home Database. Note that the top level MLS which is currently responsible for that item might belong to another GTS. In that case it is also necessary to store the identification of this GTS. Thus, the Home Database contains information of those items which have entered the ParcelCall system within the responsibility of the GTS.

A GTS which receives information about a certain item which is not registered at its Home Database forwards this information to the responsible GTS. Note that each tag must store the ID of the responsible GTS. Having both the unique ID of a transport good and the ID of the responsible GTS it is straightforward to retrieve information about this transport good.

The Transient Database

The Transient Database contains several MLS hierarchies (one for each top level MLS).
To request instant status information of a certain item, the request must be routed through the MLS hierarchy. Having the ID of the responsible top level MLS it is straightforward to retrieve the required routing information from the Transitory Database.

Note that the Transitory Database has one entry for each item which is currently under control of the GTS.

The Carrier's IT System

Among others, the GTS has an interface to the carrier's IT system. The carrier's IT system provides delivery plans to the ParcelCall system which the latter uses to build up the MLS hierarchy. On the other hand the GTS provides status information as well as alarm messages to the carrier's system.

The Goods Information Server

The Goods Information Server (GIS) provides customers status information about their transport goods. To this end a GIS connects to a carrier's GTS to retrieve this information. Basically, the GIS displays the information received from the GTS network to the user. Therefore the GIS implements a multimedia converter which allows conversion of different formats like for example HTML – WML or HTML – XML conversion.

To retrieve information about a certain transport good a user authenticates to the GIS and provides the ID of the good as well as the ID of the responsible Home Database. Having both IDs it is straightforward to retrieve the information from the GTS network.

CONCLUSIONS

In this paper we presented the ParcelCall approach towards an open architecture for tracking and tracing in transport and logistics.

The de-centralised architecture has several attractive features with respect to the requirements listed above. Most importantly, this architecture scales extremely well; it is no problem to install an additional server if need be. Almost as important, there is no need to modify existing corporate IT infrastructures. The only thing that needs to be done is specify and implement an interface between the infrastructure and the GTS. If required, incoming information (from the MLS) can first be processed internally before it is made available to the public via the

GTS network (for instance, if exact location information must not be made available for security reasons). Moreover, small companies can compete on a more level playing field.

Internal details, such as change of transport mode or use of a sub-contractor are hidden from the end-user, to whom a virtual global delivery system is presented. (Mobile) end-users (i.e., consignors and consignees) can obtain information about a consignment from the Goods Information Server (GIS). The GIS holds the individual user profiles, checks and verifies a user's identity, forwards the query to an appropriate GTS and returns the response to the user's current end system.

We believe that the European transport and logistic industry will greatly benefit from a unified architecture for the exchange of continuous tracing information. It will enable the deployment of new products and services and the improvement of existing ones.