Using the Internet in Transport Logistics – The Example of a Track & Trace System

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Abstract. The paper presents some socio-economic and technical issues that arise from the design of an open, multimodal end-to-end tracking & tracing system. An outline of the general background and the project's goals is followed by a discussion of the associated socio-economic aspects. User requirements are also addressed, with respect to the business context of the logistics environment. Subsequently, a brief overview of the project's technical design choices and is given, followed by a more detailed discussion of the individual components of this architecture.

1 Background and Goals

Europe has the most advanced transport infrastructure of the world, including 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). Unique opportunities will be generated when these two infrastructures are connected to each other.

Transport and logistics today have evolved into a high-technology industry. 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. 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 tracking and 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.

That is, continuous information about the current position or status of transport goods (in the sense that the geographic position can be queried at any time) is not commonly available today. Existing solutions are typically based on scanning bar codes at process or control points. Moreover, information at item level is not normally available either. Typically, this information is provided – if at all – at a vehicle or container level only. Furthermore, very few companies have true global or even European coverage. In daily business, products are frequently shipped by subcontractors of the transport company, which frequently means that tracking and tracing at least becomes much more difficult, and typically will no longer be possible at all. 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 TCP. This allows considerable freedom with respect to the underlying network protocols, potentially including e.g., GSM/GPRS, ISDN, UMTS, and IP. Easy integration into legacy systems, operated by the individual carriers, to the new information infrastructure is another key design criterion. Seamless interoperation between these systems on the one hand and the new tracking & tracing system has to be guaranteed.

Furthermore, and in addition to the track & trace services typically provided today, ParcelCall will enable [1]:

- item level tracking & tracing
  That is, the granularity of the track & trace function will be adjustable, from the individual item (e.g., a parcel) up to a container or a vehicle,
- 'near-real-time' (continuous) tracking
  Status and position information will be made available at anytime (not just at e.g. terminals or hubs).

The remainder of the paper is organised as follows: Chapter 2 briefly introduces the socio-economic context of the project. An overview of the user requirements from a business perspective is given in chapter 3. Subsequently, chapter 4 introduces the overall system architecture and its individual elements. Finally, some conclusions are presented in chapter 5.

2 The Socio-Economic Context

The socio-economic environment within which freight forwarders and logistics companies operate is briefly outlined in this chapter.

The success of a new technology depends on more than simply its technical efficacy; it must also be matched with its socio-economic context. In some cases this means tailoring technology to the existing environment, in others the market and context may need to be ‘created’, alongside the technology, by the technology’s developers. Most obviously a technology must address the requirements of its various users. Typically, it is important that current needs, as seen in existing business practices, are taken into account. However, although existing practices provide a starting point, gaining the full benefit of new technology often depends on its more radical application.

Tracking & tracing systems need to address the requirements of two main types of transportation: business-to-business and business-to-consumer. While the former increasingly hinges on efficient logistics management, a key issue for the latter, especially as regards the growth of e-commerce, is customer satisfaction.

High quality tracking and tracing of parcels matters for business-to-business transportation because of the trend towards inventory reduction. The speed, reliability and timeliness of delivery have increasing commercial salience both in procurement and in the quality of service offered by a supplier. Enhanced logistics management based on Just-in-Time, Vendor Managed Inventory or similar approaches can not only minimise stocks held, but can also involve outsourcing logistics management either to the supplier or to a specialist logistics operator. With e-commerce, boundaries between different ‘stages’ in the supply chain may become eroded. Distributors may take on extended roles; for example, in fulfilment and final assembly.

Improvements in tracking and tracing can also play a significant part in eliminating one of the problems faced by Internet shopping – reliable, time-assured delivery, tailored to customer requirements. Although not unique to Internet shopping, heightened customer expectations along with internet/WAP access provide an opportunity for improved customer service using more accurate parcel tracking technology.

While fulfilling these business applications is central, it is also important to recognise that there are a variety of other socio-economic issues that may affect the technology’s success. Security and confidentiality may be important. Above all, a technology that involves inter-organisational data exchange depends heavily on the success of standardisation efforts and on the willingness of firms to work together. These issues may affect the technical choices adopted in the design and configuration, as well as the commercial strategies for its promotion. Strategic thinking on these lines is embedded in the architecture and strategy of the ParcelCall project [2], [3].

3 User Requirements

The user requirements discussed in this section relate rather more to the underlying busienss processes than to a technical architecture or a specific realisation.

Attaining technical objectives will be of little significance if the technology itself is not widely implemented. Although individual companies could benefit from its local adoption, a system’s full potential lies in the development of a standardised approach that can gain general acceptance in the industry. Success will not depend simply on the development of the ‘best’ technology; equally important is the development of a constituency of users. The system will depend upon aligning expectations to ensure that a sufficient number of key users (critical mass) will be convinced to take part. It is crucial to convey that this represents the way forward, to win these kinds of commitments.

Thus, it is crucially important to recognise the diversity of players involved, with their very different commitments and needs. The development of a new Inter-Organisational Network System may involve an uneven distribution of costs and benefits between these players [4]. In particular, it is important to ensure low barriers to entry - particularly for those players for whom a sophisticated track & trace system does not offer significant immediate benefits or strategic importance.

System senders, receivers, and carriers are the main users of a tracking & tracing systems. Their respective requirements are discussed in this section. Other users include Transport Broker, Packaging Services, Collection and Delivery Services, Depot/Hub/Terminal operators, and Vehicle Drivers.

Individual senders will typically take the parcel to a collection office. Home collection could also be possible, and it should be possible to arrange this service though Internet/WAP access. The sender would like the options of email confirmation of parcel delivery, and Internet/WAP access to transit status and estimated time of arrival.

The requirements of company senders will vary according to their business practices, and companies that are supplying goods to individuals may have similar requirements to individual senders. They will want to receive as much status information as possible because this can then be provided to their customers, providing value added to their service. Likewise, reliability in delivery times (or flexibility in rearranging them) is important, as would be the ability to confirm that the parcel has been received by the appropriate individual.

Individual receivers want to know when a parcel will arrive so that they can ensure that someone is there to receive it. Internet/WAP access and email messages can provide an attractive customer service, and is, for example, likely to be an important aspect of the development of internet shopping. This service could include ‘real time’ information on the parcel’s movement, with updates in the estimated time of arrival being the key feature.

In the case of corporate receivers, their dealings with senders will often be part of long-term supply relationships. For example, in B2B e-commerce, many manufacturing receivers may use EDI to send orders or call-offs based on long-term supply agreements and these may be generated directly from their internal systems. ID tags should have the potential to satisfy any of the receivers’ internal requirements for tracking the parcel.

Companies providing express delivery, freight-forwarding and logistics management will be the main users. Their customers (senders and receivers) may have certain data requirements (as noted above), but mainly they will want a high level of performance and service to be provided to them seamlessly and transparently. While a number of large, integrated carriers mainly use their own transportation (planes, trucks, etc), even they typically need to subcontract the physical carriage some of the time.

Parcels must carry an ID tag. As with existing track & trace systems, this tag will be read at each control point – typically the hand-over between transportation units when arriving at or leaving a depot. With active tags, the reading of tags can be continuous, or at customer request rather than solely at handover points.

The carrier also requires regular feedback from moving transport units where this is possible. This information will comprise location and transport unit status (is it on time? what is the expected delay?), along with all the parcels carried and their routing, destination and estimated time of arrival.

Delays or route deviations will be identified by the system. It should also be possible for deviations to be manually notified by the transport operator. If ‘thinking tags’ are used, then any undesirable deviations in the status of the parcel (in temperature, for example) should result in alerts to both the carrier’s main system and directly to the transport unit operator so that remedial action may be taken as soon as possible. Issues arise about whether to standardise these messages and, if proprietary and encrypted messages are being transmitted, whether carriers will feel happy to pass on to third parties information that they cannot themselves understand.

4 The Architecture

This chapter discusses the system architecture (see Figure 1). An overview of the specific architecture designed by, and deployed within, the ParcelCall project is followed by a description of the individual components.

A Mobile Logistics Server (MLS), located on board a vehicle, collects information on the individual items, including position and status. The former is obtained via the Global Positioning System (GPS), ‘intelligent’ tags are utilised to collect the latter. These ‘Thinking Tags’, have also been developed within the project, can 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.).

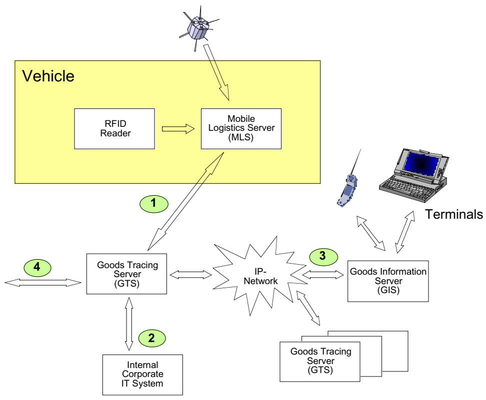

Figure 1: The System Architecture

The MLS sends the compiled information to a Goods Tracing Server (GTS). Every participating company (e.g., freight forwarders, logistics service providers, fleet operators, etc) needs to install at least one GTS which also serves as the interface between the respective internal IT system and the track & trace service. Thus, the set of GTSs forms a highly distributed data base holding the information available to the end-users (subject, of course, to appropriate access rights and successful authentication). The individual servers are interconnected via public networks (as e.g. the Internet or ISDN). 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), one (or a few) MLSs, and some 'thinking tags' are pretty much the only additional pieces of hardware required. Customers can access the system through a 'Goods Information Server' (GIS), whose tasks also include authentication and access control. The elements of this architecture are discussed below in more detail.

4.1 The Mobile Logistic Server

To provide the required services each transport unit need to be equipped with a Mobile Logistic Server (MLS; see Figure 2) which keeps track of the goods within that unit. A transport unit may, for instance, be a truck, a freight wagon, or a container.

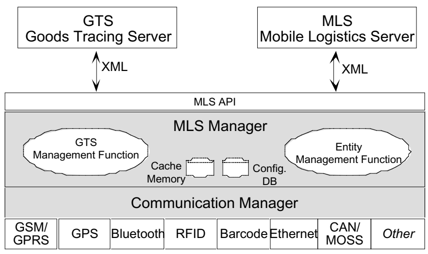

Figure 2: Structure of an Mobile Logistic Server

Each such unit may contain transport goods or other units, thus potentially forming a hierarchy of transport units. Since each unit might have a MLS, the transport unit hierarchy causes an equivalent MLS hierarchy. Except for the top level MLS (root of the hierarchy tree) all MLSs communicate with their respective superior and subordinate MLSs.

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From an MLS's point of view there is no difference between a tag and an MLS. A 'normal' MLS only needs to implement an item[1] interface. Only a top level MLS must implement an item interface and a GTS interface.

Both 'thinking tags' and MLSs store a unique item identifier, the item's destination address, and certain other information, as e.g., constraints on e.g. temperature, shocks, or humidity. If a threshold of one of these constraints is exceeded an event will be

[1] Both goods and transport units within a container are subsequently referred to as 'items'.

generated and passed to an superior MLS, which forwards the event to its associated GTS. The GTS, in turn, forwards the event to the carrier's IT system (which may or may not react upon the event). If a transport unit within this message chain has a control system (e.g., for a refrigeration unit), this control system can register with its associated MLS to receive events. Thus, transport units can also react immediately 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 (due to, e.g., poor GSM coverage) and thus cannot receive any instructions.

Unloading and re-loading of transport units changes the MLS hierarchy. To keep track of such 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 can receive a loading list of 'its' items in advance from a GTS. While an item is scanned the MLS checks whether or not it is on its loading list and generates an alarm message if a 'wrong' item has been detected. Likewise, the responsible GTS is informed when the loading procedure has been completed successfully.

4.2 The Goods Tracing Server

The GTS network forms the backbone of the ParcelCall system (see Figure 3). It interconnects and integrates the individual ParcelCall servers on the one hand, and the individual carriers' IT systems on the other. A GTS comprises of two databases: A Home Database and a Transitory Database. The Home Database contains item information, e.g. an item's current position, its expected time of delivery, etc. The Transitory Database holds the MLS hierarchies.

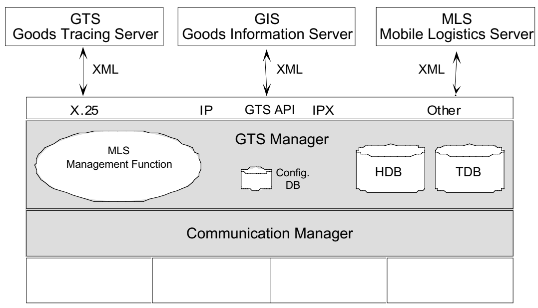

Figure 3: GTS Internal Architecture

The Home Database. As 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 with the GTS or with an MLS. The latter forwards registration information to the local GTS, which 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 system within the responsibility of the GTS.

A GTS receiving information about a certain item which is not registered at its Home Database forwards this information to the responsible GTS (the ID of which is stored in the tag). Having both the unique ID of an item and the ID of the responsible GTS it is straightforward to retrieve information about this transport good.

The Transient Database. It 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 obtained 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 a carrier's IT system. This system provides delivery plans to the ParcelCall system which are used to establish the MLS hierarchy. On the other hand, the GTS forwards status information and alarm messages to the carrier's system.

4.3 The Goods Information Server

The Goods Information Server (GIS; Figure 4) provides customers with 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, it implements a multimedia converter which allows conversion of different. The GIS also performs user authentication and manages the access control.

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.

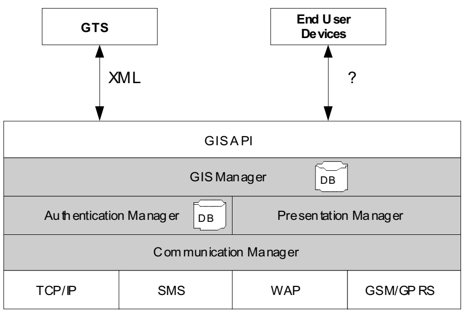

Figure 4: The GIS Architecture

4.4 Passive and Active Tags

Passive RFID (Radio Frequency Identification) tags are available today at moderate costs, and can easily be integrated into labels holding e.g. bar code information. Due to the costs (compared to 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, we believe that it is only a matter of a few years before RFID tags will 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 bar code labels with RFID tags will enable automatic identification 'on the fly' without the need for manual consignment handling and label scanning. As a further step, 'Thinking Tags' could be used instead of passive RFID tags. Such tags, which have been developed within the project, combine active short-range communication capabilities with sensing, memory, and computing power. Key issues in their design include low power consumption and low costs.

Thinking Tags will offer opportunities far beyond the mere transmission of static identification information, including, but certainly not limited to:

- continuous measuring and monitoring of environmental conditions (temperature, humidity) for sensitive shipments (e. g., frozen food) at individual item level,
- 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, environmental conditions, status) of a shipment in order to provide evidence in case of liability issues.

5 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 identified requirements. 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 customers will benefit from improved information on their shipments; their potential benefits include, but are not limited to improved planning, and better management of supply chains and inventories.

Likewise, the European transport and logistics 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.

6 Acknowledgement

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