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Intermodal Baggage Handling Technologies

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Extended Abstract

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1 Introduction

A fundamental aspect of the long distance traveling domain is the efficient handling of passengers' baggage. Every year, a large number of people need to travel for varied reasons and their luggage timely delivery must be correctly addressed.

One of the problems which hasn't been solved yet regards the current baggage handling systems inability to perform passenger-baggage reconciliation along an intermodal trip involving other transportation means besides aircraft.

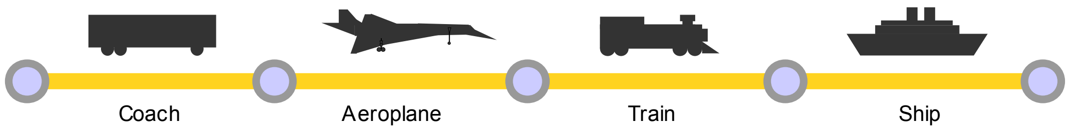

Figure 1: Intermodal trip

The objective of this work consists in the attempt to find a viable solution for the limitations stirring current baggage handling systems, which confine baggage monitoring to each airport's internal baggage circuits. Thus, a study was elaborated concerning the current baggage handling state of the art in order to find the adequate tools to solve this problem in a prolific way. This study was followed by the implementation of a prototype which would address certain aspects of the intermodal context.

Summarily, it is proposed to insert all information relevant to the baggage handling operations within the luggage items own identification devices, which correspond to radio-frequency identification (RFID) tags. This task will be executed resorting to paradigms usually employed in the automated fare collection domain, from public transportation. The particular characteristics of this domain may sustain the presence of baggage handling information in the tags from three main points of view: information portability, information security and handling operators integration.

2 Context

The current bagagge handling processes were not built with the intermodal traveling needs in mind. Only the commercial flight domain uses technologically advanced systems, which employ more traditional bar code identification tags or even RFID tags. However, RFID technology *per se* is not enough to solve all the intermodality related problems. It is necessary to revisit the existing business process models in order to outcome the current systems limitations.

Nowadays, bagagge handling is not processed from a door-to-door perspective. As a matter of fact, each airport is responsible for monitoring all passengers' luggage in their own restricted baggage distribution circuits. Messages are sent to and received from other airports whenever necessary concerning inbound and outbound luggage. A single identification serial number called license plate is recorded in each bar code or RFID tag attached to a luggage item (Vogel 2007), but the associated reconciliation data remains in backend systems. This reconciliation data is useful to all handing operations, such as sorting, loading, etc. Nevertheless, if a system failure impedes the reception of the required data to process a certain baggage item, it is extremely difficult to apprehend what to do with it. The only alternatives left are to send back the baggage to its previous location, or to keep it in a some warehouse until someone reclaims it.

But what would be the role of the automated fare collection paradigms in baggage handling? In this domain, it is not uncommon to place the data related to the transportation network access rights in the customers electronic tickets. This may seem similar to the idea of storing the reconciliation data in the baggage tags.

2.1 TSMART

The TSMART proposal – Tags for SMARt Travellers – relates to a project whose objective is to surpass all current baggage handling systems limitations (TSMART 2007) and it was the original inspiration for this work. From the TSMART proposal point of view, baggage handling should be done door-to-door resorting to advanced RFID tagging and peer-to-peer (P2P) networking technologies. Baggage would be identified by the RFID tags, and the associated reconciliation data would "follow the tags" along the trip, provided that the data flowed through the P2P network. The alternative proposed is the inclusion of all reconciliation data in the tags themselves. Among other things, TSMART services would enable passenger notification of their current baggage status by SMS or Internet access, remote check-in by NFC technology – Near Field Communication – and even better group trip traveling by segregating passenger related tasks from baggage carrying operations.

2.2 Assumptions

The main idea of automated fare collection is the substitution of legacy paper tickets by electronic tickets, allowing easier transaction analysis and enabling more efficient service and route planning. As it was referred before, automated fare collection addresses the three previously referred issues: offline operations support, data security and handling agents interoperability.

2.2.1 Offline operations support

The backend systems typically contain all the reconciliation data in respect to a certain luggage item. Any unsuccessful data transmission attempt results in the impossibility to handle that item. However, if that data 'follows' the identification tag, offline support is guaranteed (e.g. in a coach trip). In the automated fare collection domain, customers tickets or cards contain the necessary data which grants them the right to access the transportation networks. Buses or trams carry embedded systems onboard that process the ticket/card data and log all meaningful events. When they arrive at any main station, all data is downloaded to a central server, where all the data warehousing operations take place. A similar infrastructure could be in implemented in the case of baggage handling, since data would be similarly contained inside the tags themselves.

2.2.2 Interoperability

Since all reconciliation data is to be stored in the tags, it must be unambiguously interpreted by all the handling operators. In the automated fare collection domain, customers hop in and out of different means of transportation using a single ticket/card like the 'Lisboa Viva' card (Link 2002). A data model is defined in order to formally structure all the data related to the participating operators, and it allows a smooth transition between distinct operator contexts.

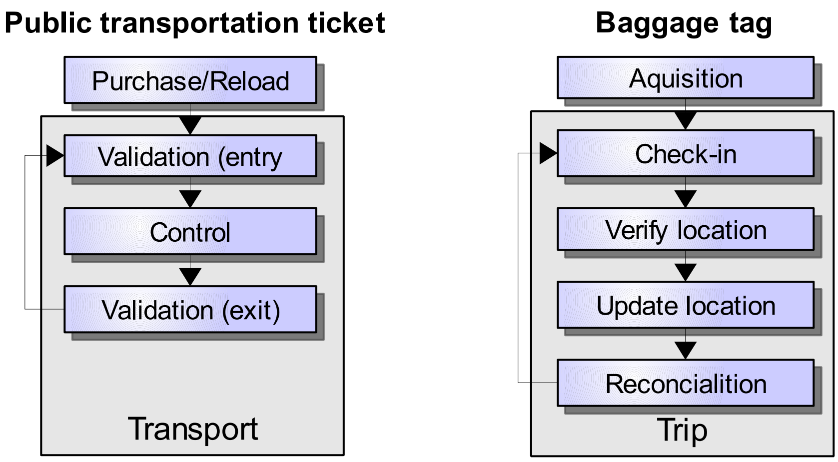

Figure 2: Public transportation ticket/Baggage tag analogy

The life cycle of baggage tags may mimic the existing public transportation tickets cycle. How exactly? By following the (re)load–validate cycle, which would translate into a check-in–reconciliation cycle. This would be particularly interesting because tags could be reused after the end of each trip. The totality of trip data would be written in the tags at check-in, and then tag status would be updated at specific checkpoints throughout the trip. Hence, it would be passengers' responsibility to attach their tags to the bags, and then to reload them with the next trip's data.

2.2.3 Data Security

In contrast to the traditional handler managed baggage tags, a consequences of the proposed passenger managed tags would be the increased exposure of sensitive data. This data was previously secure in backend systems behind firewalls, but now it is literally traveling around the world. The tags are manipulated by elements external to the restricted airport environment. Thus, it is necessary to safeguard the baggage tags contents through security mechanisms. These can obscure the data to unauthorised readers and authenticate all modifications made to the data. Automated fare collection employs an established security platform to support the reliable use of electronic ticketing tecnology called Calypso (Levy 2005). An architecture similar to this could be implemented to assure baggage tag security.

3 State of the art

3.1 BHS and BRS

Baggage is currently submitted to baggage handling systems (BHS) and baggage reconciliation systems (BRS) for processing. Both are automated systems which monitor and transport luggage from the check-in counter to the aeroplane's cargo bay. Communication inside an airport and between different airports is established by the exchange of baggage information messages (BIM). These follow the IATA – International Air Transport Association – recommended practices for baggage handling (Vogel 2007). These systems have limitations related to the lack of support of other transportation means and to the inability to monitor hand carried baggage items not delivered at the check-in counters.

The components of a BHS/BRS include:

- Check-in counters where baggage is delivered;
- Belt conveyors which move luggage to the correct place;
- Transfer trays to sort and forward luggage adequately;
- Identification devices to recognise luggage items;
- Security countermeasures such as X-ray monitoring machines and explosive detectors.

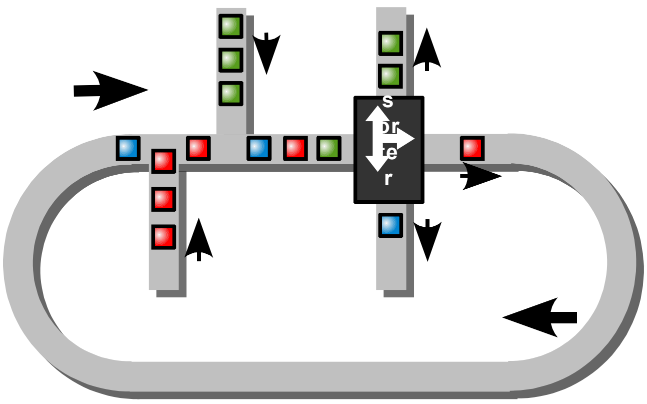

Figure 3: BHS/BRS circuits inside airports

RFID tags are increasing in popularity because their price has been dropping in the late few years, and especially because they have a better successful reading rate than the traditional bar code tags (Shafer 2004), due to being less prone to suffer physical damage.

3.2 RFID

Born during WWII in an attempt to identify friendly aircraft, radio frequency identification technology (RFID) allows the identification and tracking of objects in an automated manner. It is composed by three main components: readers/transceivers, tags/transponders, and information technology (IT).

RFID tags consist in a chip and an antenna which, according to their configuration, may work in different frequencies of the electromagnetic spectrum and, as a result, have different operating distance ranges, data transfer rates or environmental elements tolerance (Bitkom 2005). The tags may be read-only or read/write, and have different memory capacity. According to their power source, RFID tags can be passive, semi-passive or active. Anti-collision protocols such as ALOHA manage the communication of multiple tags in the active field of a single reader.

3.2.1 Contactless smart cards

This technology is employed in applications which require personal data protection or in secure transactions (SCA 2004). They are usually used in payment and identity authentication operations. The Calypso card is an example of this technology, and it is typically used in public transportation.

3.2.2 EPCglobal

The EPCglobal initiative was born from the conjoint effort of multiple enterprises in the technology and distribution fields to commercialise RFID systems and reduce the costs and risks of their implementation. It assumes that someday every object will have its own webpage in a real 'Internet of Things'. The architecture of EPCglobal systems is constituted by different hardware, software and standardisation components, which support three primary activities (EPCglobal 2007):

- EPC Physical Object Exchange
- EPC Data Exchange
- EPC Infrastructure

The current generation tags (Gen 2) are defined by a class hierarchy according to their passive/active nature and read/write capabilities. The ISO – International Organization for Standardization – has recently adopted the Gen 2 EPCglobal tags as the ISO/IEC 18000-6C standard. In terms of security, EPC Gen 2 tags have two basic functionalities: a 32 bit password which allows to neutralise tags (*Kill* command) and an optional 32 bit password which enables writing in protected memory locations. However, they are still susceptible to cloning and the the referred factory security features do not present a real challenge to a resolute hacker (SCA 2006) (Konidala 2007).

3.2.3 Calypso

The Calypso technology consists in a reference platform especially built to support the particular needs of public transportation. Its objective is to allow the implementation of automated fare collection systems in a secure, fast and flexible fashion. Includes several non technical elements which allow its use by any transport operator (eEurope 2003). The Calypso card is part of an information systems architecture that enables the transfer and verification of transportation rights – contracts, – protecting them through cryptographic algorithms. It usually contains user data, recent transaction logs, etc. (Levy 2005)

The cryptographic algorithms are based upon secret passwords stored in secure application modules (SAM), which act as real safes for the data they contain. In reality, they are simply secure smartcards coupled to ticket/card validation machines. After their manufacture, Calypso cards are personalised by the writing of secret keys and application data. During their life cycle, these cards are (re)loaded with transportation tokens and used in validation machines.

Furthermore, there are three particularly relevant mechanisms in Calypso systems, namely diversification, secure session and ratification. The first relates to the definition of unique card secret keys, the second refers to the transactional support of operations, and the last one refers to the customer 'memorisation' between consecutive network access attempts.

3.2.4 Telematics

Telematics consists in a fusion between wireless telecommunications and computer technology with the purpose to efficiently transmit information through vast networks. The Internet itself is based upon this principle. In this domain, GNSS enabled devices – Global Navigation Satellite System – are used to track items throughout their course, using the existing GSM/GPRS infrastructure to transmit data (BusinessWire 2006). They can be used in security and logistic applications. Some manufacturers have been announcing the use of this technology in baggage location applications. A passenger places a small device inside their bags and may track its position from a Web portal. This can be useful when any luggage item is lost during a trip, and the passenger wants to rapidly locate it.

3.2.5 WiFi-ID

The WiFi-ID principle is similar to the RFID concept, except it uses WiFi protocol enabled devices, mainly active transponders, to locate items (Rutanen 2008). It is popular in medical care applications, in order to locate or monitor medical equipment or even patients and personnel (Ikonen 2006). There are two available methods to determine entities location which make this technology appropriate for both short or long range uses.

4 Project development

This works consisted in a series of steps to be taken in order to achieved the final goal of building a small functional prototype. The following table describes the sequence of tasks taken.

The business processes models refer to the main activities that had to be addressed:

- passenger/baggage reconciliation, which allows to detect if there is any luggage missing in each trip segment;
- wrong baggage location detection, based upon the trip information stored in the tags.

Step	Task	Description
1	TSMART proposal requirements analysis	Use case and scenario studying.
2	Business process modeling and information entities identification	Process and information architectures modeling based upon identified requirements.
3	State of the art	Baggage handling: currently employed techniques and potentially useful technology analysis and study.
4	Embedded Framework and automated fare collection analysis	Analysis of both the automated fare collection domain and a particular instance of a Calypso system.
5	Data model definition	Establishment of a data model based upon the previously modeled process and information architectures.
6	Physical layout mapping	Physical mapping of the data model on RFID transponders.
7	Functional prototype implementation	Implementation of a testing prototype in order to execute some of the initially defined business processes using embedded systems.
8	Testing and validation	Functionality testing, model-implementation validation and conclusion formulation.

Figure 4: Project development tasks

An entity model was then built based on the business processes created. This allows one to have a better overview of the relations between all the data entities in the form of a class diagram.

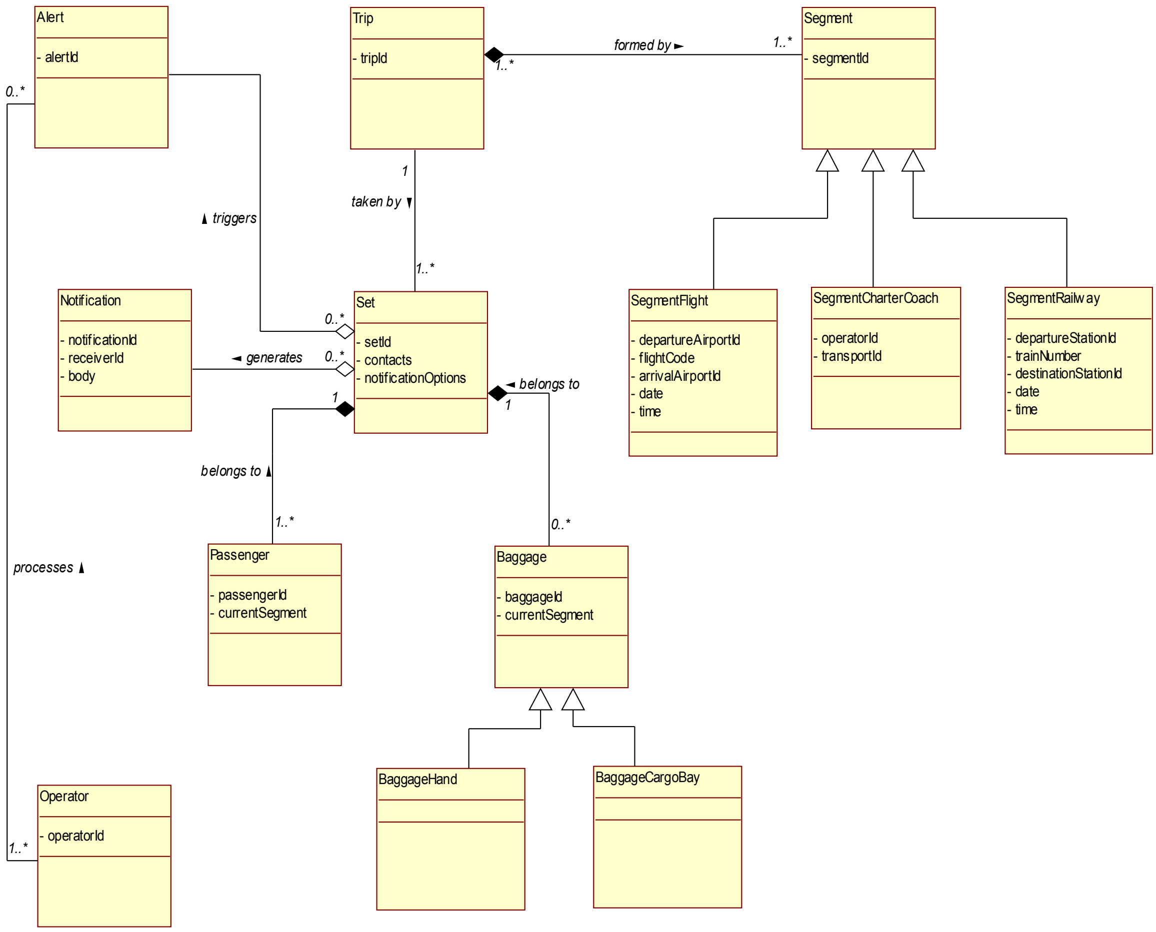

Figure 5: Entity data model

Not all the represented entities are to be stored directly in the baggage tags. Instead, some of them are only related to passenger notifications about current baggage status or personnel alerts useful to retrieve any luggage items detected missing or in the wrong location.

The actual functional prototype was built following in a multi-tier logic, and at its core is Link Consulting's Embedded Framework technology. This technology consists of multi-layered service oriented architecture in which every layer only depends on the presented interface a lower layer, through application to hardware levels. As a result, it is a very flexible tool since it allows developers to have a high level of abstraction regarding each layers' internal functionality. Hence, varied kinds of hardware may have a common framework upon which applications can be built. Development using the Embedded Framework is done following a few iterative tasks:

1. Physical layout design of the device
2. Data model definition
3. Physical mapping of the data model
4. Business rules establishment
5. Generation of the compiled Embedded Framework
6. Embedded Framework deployment
7. Testing and validation

In this work there were used RFID devices whose memory space initially needed to be mapped, so that every data model element could be introduced afterwards. There are two main memory zones, based on the contract/event area concepts belonging to the automated fare collection domain. The 'Trip Data' area relates to reconciliation data and contains all the passenger-baggage set data, as well as trip related data. On the other hand, the 'Trip Status' area is used to represent the current status of the item being monitored, and is useful to determine where the luggage should be each time it is detected. The following tables show how data was stored in the baggage tags in this particular case.

Name	Size	POS	Description	Format
TagType	3		Type of identifier tag	0 - Unknown 1 - Passenger 2 - Hand Baggage 3 - Checked-in Baggage 4..7 - RFU
SetID	24		Unique set identifier	
GroupIDBitmap	1			T_Bitmap
GroupID	24	[0]	Unique group identifier	
TotalPassengers	3		Total number of passengers in the set	
TotalCheckedInBaggageItems	5		Total number of hand baggage items in the set	
TotalHandBaggageItems	5		Total number of checked-in baggage items in the set	
TotalTripSegments	4		Total number of segments of the trip	
TripSegment	…			T_TripSegment
Total:	69			

Figure 6: 'Trip data' element

Name	Size	Description	Format	Name
CurrentTripSegment	4		Active segment of the trip	
CurrentTripStanding	4		Current trip state	0 - Unknown 1 - Not started 2 - En route 3 - Finished 4 - Sending back 5 - Redirecting 6..15 - RFU
LastEventCode	4		Last operation result	0 - Unknown 1 - Location OK 2 - Location invalid 3..15 - RFU
SequenceNumber	4			
Certificate	16			
Total:	32			

Figure 7: 'Trip status' element

5 Validation

The achieved solution validation can be done from two different points of view: functional analysis of the demonstration prototype and consistency verification of the created models. The first approach not only allows to verify if all the implemented features are functioning correctly by testing them, but also allows to analyse the efficiency of the technological base of the implementation.

Testing was done in a layer by layer manner and showed that all features were correctly implemented. However, technological limitations such as the reduced memory space of the transponders used influenced the omission of certain data fields from the data model. These were related to a few accessory features referred in the TSMART proposal, like passenger notification contact, for instance. Nevertheless, all the data elements related to the core features remained untouched.

In respect to the data transmission efficiency, a question one may ask relates to the fact that there is an extra overload of the aerial interface if reconciliation data is stored in the tags. Instead of only transmitting the correspondent serial number to the reader, each tag must transmit additional data, thus occupying the communication channel for longer periods. This is caused by the existence of the anti-collision protocols (e.g. ALOHA). Additionally, the nature of signal modulation constrains the maximum data transfer rate at which RFID tags may backscatter their contents, and it usually depends on environmental characteristics, distance, etc. Not to forget that security features, such as certificate generation to authenticate data written on the tags, also introduce a slight overhead. Finally, tag filtering (Bai 2006) is an important tool in the sense that it processes raw tag data to allow the correct interpretation and integration of data at the application level.

The starting point for the models consistency verification was the analysis of the existing relation between the created data model for the transponders and the process and entity models. As one may imagine, there must exist a coherent correspondence between each element of the data model and the information entities required for the correct execution of the business processes. The elimination of one of these elements would impede the regular flux of baggage handling operations.

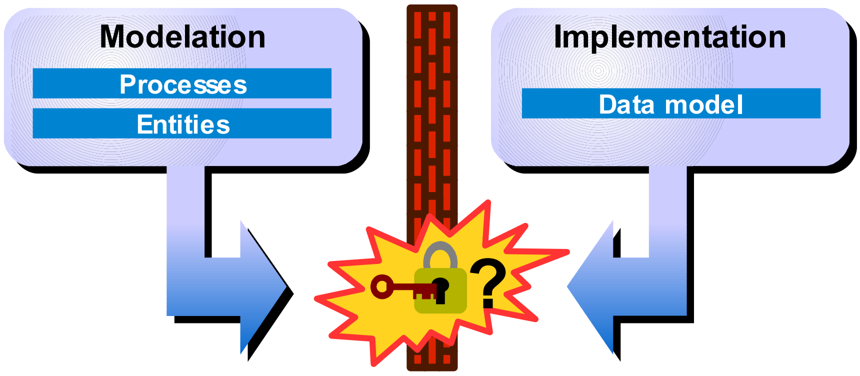

Figure 8: Intermodal trip

Consequently, since all the represented elements have a direct connection to the entity model, the data model is considered to be valid and built in legitimate manner. However, as it was referred before, some of the initially proposed elements were omitted, namely some of required for accessory passenger services as described in the TSMART proposal. This was required due to tag memory space limitations. The decision was taken in order to guarantee that there would be enough space for all the remaining elements, which were undoubtedly mission critical.

6 Conclusion

An adaptation to real world conditions is never easy, because not all possible variables may have been accounted for in a test scenario. In this case, the adoption of automated fare collection paradigms has proven to be plausible since it addressed the main problems related to the extension of baggage handling systems to an intermodal traveling context.

At the offline operations support level, the presence of portable reconciliation data in the tags proved to be very helpful, despite the problems related to memory space constraints. The initial definition of the business processes and information entity relations has shown that these are the unavoidable building blocks of consistent and effective RFID based systems, providing a formal methodology of system implementation as shown in other IT areas.

In respect to the security issues, automated fare collection provides an excellent source of information to get the best practices to employ in the building of secure and reliable RFID systems. Even though the logistics field has its own security policies and technologies, it is still far from established references such as the Calypso standard.

Concerning the handling agents interoperability, automated fare collection introduced concepts which improved the representation of data in a systematic, unambiguous fashion, which allows a smooth integrates all agents involved in baggage handling. Nevertheless, the extension of the baggage handling domain to intermodal traveling surpasses the own automated fare collection domain. This means that additional standardization efforts must exist.

7 References

Bai, Yijian e Wang, Fusheng e Liu, Peya (2006), *Efficiently Filtering RFID Data Streams*, CleanDB, Seoul, Korea

BITKOM (2005), *RFID White Paper Technology, Systems, and Applications*

BusinessWire (2006), *Air Travelers Rejoice: MicroTRAK Offers SlimTRAK GPS Location Tracking Device as Answer to Airlines' Lost Luggage Dilemma*, retrieved on 15/6/2008, from http://www.thefreelibrary.com/Air+Travelers+Rejoice:+MicroTRAK+Offers+SlimTRAK+GPS+Location...-a0143245006

eEurope Smart Cards Initiative (2003), *Open Smart Card Infrastructure for Europe*

EPCglobal (2007), *The EPCglobal Architecture Framework 1.2*

Ikonen, Jarmo (2006), *Asset management & tracking Process Tracking Security*, Ekahau, retrieved on 13/2/2008, from http://www.kirtech.com.au/rtls/downloads/ekahau/Ekahau_Hospital_Case_Studies.pdf

Konidala, Divyan M. e Kim, Zeen e Kim, Kwangjo (2007), *A Simple and Cost-effective RFID Tag-Reader Mutual Authentication Scheme*, Korea ICU/IRIS/Auto-ID Lab

Levy, Frederic (2005), *Calypso Functional Specification Card Application*, Innovatron/RATP/SNCF/Spirtech

Link (2002), *Lisboa Viva – o Cartão da Mudança*, retrieved on 7/2/2008, from http://www.link.pt/upl/%7B9f7bcdd3-e493-4114-bbf3-74bfc971324e%7D.pdf

Rutanen, Tuomo (2008), *Real time location (RTLS) with Wi-Fi*, RFIDswitchboard, retrieved on 13/2/2008, from http://www.rfidsb.com/index.php?page=rfidsbRealTime&c_ID=119

Shafer, Mark e Sayeed, Faique (2004), *RFID: Opportunities and Advantages in Baggage Handling*, nextFrequency LLC White Paper Series

Smart Card Alliance (2006), *Contactless Smart Cards vs. EPC Gen 2 RFID Tags: Frequently Asked Questions*, Smart Card Alliance Identity Council

TSMART (2007)*, Tags for SMARt Travellers: a Multi-Modal Luggage and Passenger Conciliation Platform for Door to Door Service*

Vogel, Thomas (2007), *Technical System Specification to RFID-enable the Baggage Sorting Problem at Zurich Airport*, Master Thesis, ETH Zürich