eTracer: An Innovative Object Tracking and Tracing Platform

EFI PAPATHEOCHAROUS, ANDREAS S. ANDREOU
Department of Computer Science
University of Cyprus
75 Kallipoleos Avenue, CY1678, Nicosia
CYPRUS
efi.papatheocharous@cs.ucy.ac.cy, aandreou@cs.ucy.ac.cy

VASILEIOS KONSTANTINIDIS
R&D Department
DATATECH
70, Stadiou Str., 2057 Nicosia, Cyprus
CYPRUS
vasileiosk@datatech.com.cy

Abstract: - Near real-time tracking of objects is becoming a critical requirement in transportation business today since competition is increasing and customers are becoming more demanding in obtaining information on services and delivery of products. The technological advancements in the fields of networking (e.g., 3G, HSDPA), near field communications (e.g., RFID) and location identification (e.g., AGPS) provide the potential for the creation of an advanced intelligent tracking platform that identifies and captures an object all across its lifecycle. In the current paper we present such an innovative platform; eTracer which is an end-to-end near real-time tracking platform for objects. In addition, the architecture of eTracer is analyzed and the research issue of reducing the computational intensiveness of processing is also discussed.

Key-Words: - Object Tracking, Tracing, RFID Processing, Logistics Management, Business Intelligence

1 Introduction

The need for a monitoring, detection and tracing platform in the sector of transports of goods is continuously increasing. The competition between the enterprises doing business in the specific sector is often high and consequently these companies try to find ways to increase their efficiency and decrease their expenses. In addition, the customers often require monitoring and tracing services because they want to be aware both of the locality of their charges as well as of when to expect them. In addition, there is an increasing need for detailed information regarding the track of transport services of goods and delivery commitments. The transport business also faces the challenge of different enterprises collaborating in the same supply chain. Due to the large number of enterprises, the knowledge of the precise location of the merchandises at object-level is often difficult. Monitoring, detection and tracing systems, such as electronic labels or readers or transmitters, may offer a viable solution to this problem. Amongst the motives for the adoption and diffusion of such platforms, the following may be included:

- Increasing awareness and market familiarization of monitoring, detection and tracing systems and applications.
- Planning for the reduction of costs and for increasing the quality of services.
- Increasing customer needs and pressure for real-time tracking information of their goods and services.
- Low cost technological advancements overcoming current barriers and increasing security and communication confidentiality.

The main objective of the innovative eTracer platform is the real-time improvement of the main transportation management processes and advancing the business intelligence including:

- The allocation of the transportation plan to the most appropriate transporter.
• The monitoring, loading and unloading of products and goods in an automated way, while at the same time updating the operational enterprises’ applications (e.g. ERP, SCM, etc.).

• The monitoring of the transportation status of the goods with on-time representation of the vehicle position on an interactive map (including the geographic background).

eTracer constitutes a near real-time, innovative platform of end-to-end monitoring, detection and tracing of transports of goods, which operates through different carriers and ways of transport, at individual object level. The innovative eTracer platform improves in terms of real-time the operational processes of transport and logistics for the transportation and supply enterprises. The basic idea behind the offered service is the integration of a series of technologies (including GPRS, GPS and RFID) and the utilization of current protocols and standards (including EPC, TCP/IP, Bluetooth and WLAN), in order to combine Radio-Frequency Identification Tags (RFID) with telematics and wireless technologies in order to provide a wide range of operational, territorial and time-based information.

However, near real-time object tracking is accompanied by a series of research and technological challenges that the eTracer service needs to cope with and overcome. In the following section an overview of the research issues and requirements that are raised in the domain of Object Tracking is provided, while in parallel our contribution is described. In section 3 the implemented architecture is analyzed. Moreover a more detailed view of a data reduction algorithm that aims at the acceleration of post-processing is provided. Finally, section 4 concludes the paper.

2 Related Work

2.1 Progress and Challenges in the Track & Trace Domain

The effect of efficient object tracking not only helps during the real-time transactions but also has significant post-processing value concerning the identification of objects that are even lost or misplaced [1]. Automatic object tracking records through tagging can greatly assist in efficiently managing such transferable objects and benefit organizations.

Regarding the abovementioned issue, the Radio Frequency IDentification (RFID) technology [2], [3] has emerged as a practical solution to aid automatic object identification and tracking. These wireless technologies enable reading from a distance and their deployment is highly effective in manufacturing and other ‘hostile’ environments where the employment of bar code labels is infeasible or impractical. RFID being a non-contact and non-line-of-sight technology triumphs over bar code labels especially for tracking mobile objects because they can be easily read regardless of orientation and distance. Also, RFID has prevailed the automatic identification scenario via low cost transponders offering multi-read capabilities, low to reasonably high (64Kbits) data storage capability, wide range of data transfer rates (depending on the device and carrier frequency used) and close proximity (inductive systems) to tens of meters (radiating systems) without the need for line-of-sight interrogation. This technology can be used very efficiently to pervasively tag physical objects so that they can be tracked at any time required through the entire path of transactional processes. By the term transaction, we basically qualify the movement of a tagged object from its source to the destination passing through different organizations and hierarchy and possibly changing ownership in the process. It has been rightfully pointed out in [4] that RFID tags are wireless, networked, pervasive computers, successfully integrated into their environment. This nascent concept of pervasive RFID tag deployment offers very high potentials for many application areas such as mobile commerce [5] increasing their efficiency.

With RFID technology, it is possible to create a physically linked world in which every object is identified, numbered, cataloged, tracked and traced. RFID tracking is fully automatic and fast, and does not require line-of-sight or contact between readers and tagged objects. To achieve these, the first task for RFID applications is to map objects and their behaviors in the physical world into the virtual counterparts and their virtual behaviors in the applications by semantically interpreting and transforming the RFID data.

There are generally two types of RFID applications: i) history-oriented object tracking and ii) real-time-oriented monitoring. Both application types need to transform RFID observations into logic data [6]. In the history-oriented object tracking applications, RFID data streams are collected from multiple RFID readers at distributed locations and transformed into semantic data stored in the RFID data store. The semantics of the data include:
• **Location**, which can be either a geographic location or a symbolic location such as a warehouse, a shipping route etc. The change of location of an RFID-tagged object is often signified by certain RFID readers. The location history (travel history) of RFID objects is then transformed automatically from these RFID readings, and stored in the location history relation in an RFID data store [7];

• **Aggregation**, i.e., the formation of relationships among objects. A common case is the containment relationship. Commonly, it has been identified that the association relationship among RFID objects in an Auto-ID environment is a difficult issue for RFID applications [8].

• **Volatility**, i.e., the possibility of constant change, since RFID observations and data collected are highly temporal, as also described in [7].

On the other hand, in real-time monitoring applications the patterns of RFID observations imply special application logic that can trigger real-time response. Both history-oriented and real-time-oriented applications are utilized in order to apply specific queries. Such indicative queries that may be posed on the RFID streams include [9]:

• **Tracking queries**, which include queries such as “report any object that has deviated from its intended path,” or “list the path taken by an object through a restricted zone before it was misplaced/lost.” Such tracking queries are location queries that require object locations or location histories.

• **Containment queries**, which include queries such as “raise an alert if an object item does not exist in a specific location”. This class of queries involves inter-object relationships e.g., containment between objects, cases, and pallets, and are useful for enforcing packaging and shipping regulations.

• **Hybrid queries**, which include “for any temperature sensitive drug product, raise an alert if it has been placed outside a freezer and exposed to room temperature for 6 hours.” This class of queries combine sensors streams (e.g., temperature) and RFID streams (e.g., object location and containment) to detect various conditions.

Unfortunately, the nature of RFID data makes these queries difficult to answer. The key challenge is that although such queries typically involve object locations and inter-object relationships such as containment, the RFID data do not directly contain this information. Rather, the data contain only the observed tag ID and the reader ID; something which is a fundamental limitation of the RFID technology.

### 2.2 Our contribution

Taking under consideration the above technological progress and the existing challenges we created a system that is tailored for the Courier business domain and provides near real-time end-to-end tracking of exchanged objects (i.e., parcels, packages, cargo, envelopes and freight). The first technological challenge that had to be tackled was data fusion. Data fusion is correlated with the different channels of communication that needed to be utilized in order to acquire a full set of data on which specific queries could be applied. This data was addressed as “raw data” because it did not include semantic information. In order to achieve data fusion many software/hardware components needed to interoperate. Indicative components included handheld devices, for picking up an object and providing the initial matching between the process ID and the RFID tag, fixed gates, mobile gates, etc. All these components are described in more detail in section 3.1.

The next technological challenge tackled was semantic ‘uplifting’. The difficulties raised during semantic uplifting were many. First of all, the computational barrier was tackled. The problem of extracting meaningful states (and transitions) for an object, based on raw information regarding the existence of an object in time and space, is equivalent to a computational intensive matching sub-graph. Furthermore, a system that is based on distributed sources of information is totally asynchronous which implies that many problems may rise from the lack of a part of information (e.g., an object-delivery is successfully traced but its delegation to the delivery-responsible is never tracked). Concerning semantic uplifting, in this paper, the data reduction policy followed in order to restrict the computational intensiveness of state-extraction is analyzed.

### 3 The eTracer Platform

#### 3.1 System Architecture

Figure 1 presents the system architecture of the eTracer platform and signifies the points of interaction between the various types of users (i.e., customers and authorized employees of a Courier company for
transferring goods). As indicated in Figure 1, the data between different software applications and subsystems are being collected, processed, managed and exchanged in the following manner.

First of all, each object (package) for delivery is identified by a courier order. The employee of the transport company (acting as a receptor or carrier of an object), through the use of portable equipment and the object detection system, comprising the Portable Logistics Devices Network, initially affixes an RFID tag on the object accepted for transfer and correlates the number of the courier order with the unique identification number of the RFID tag. The correlation is carried out using a Portable RFID Reader. Then, the employee using a GPS receiver, built into the portable equipment, collects and sends all the required data for the object with the exact location by using the mobile networks that are available in the region (usually via GPRS).

The transport vehicles (including motorcycles, trucks and other motor transport methods) comprise the Mobile Logistics Stations Network, and are used to detect objects during loading. Each courier vehicle utilizes specialized equipment of RFID readers to detect and identify all the RFID tags on the packages entering and exiting the transport vehicles, and thus they identify all the objects (e.g., parcels) located in the vehicles at all times. In addition, each courier vehicle has a GPS receiver and a GPRS wireless transmitter installed that can provide the exact location of the objects carried at any given time.

Figure 1 System Architecture of the eTracer Platform

The logistic stations (courier depots, hubs, or stations) where packages are concentrated constitute the Fixed Logistics Stations Network and also have specialized equipment installed, i.e., RFID readers at the entrances, as well as extra RFID readers at the internal entrances of the interior of the stations (rooms or sections). This way, each logistic station is able to detect and identify all the RFID tags found in packages both entering and exiting the entry points of the station entrances as well as the indoor entrances, identifying all parcels located in any area within the station at any time. Using Wireless LAN (WLAN), the detected and identified RFID tags and the data corresponding to the identified (tracked) objects are collected by the Local Communication and Data Exchange Web Server to be promoted from there to the central information system of eTracer.

The raw data collected and managed through the portable and wireless networks of mobile equipment for object detection are sent using mobile networks (GSM/GPRS) to the eTracer service. This incorporates a gateway for data exchange between the mobile network and the IP-based intranet infrastructure of the integrated eTracer information system and forwards the data to the Web Communication Server, which carries
out mediation between the eTracer Subsystems and the remote units of detection. The data managed by the
pre-installed detection stations (Fixed Logistics Stations) and the data of objects collected in the Local
Communication Servers are sent via internet to the centralized Communication Web Server which is the
backbone of the subsystem of eTracer responsible for the detection and identification of objects.

The intelligent Tracking and Tracing Subsystem of eTracer is responsible to detect, identify, classify
primary data of the objects and store them in a central relational database, where it is further exploited for
analyses, statistics and reports.

Finally, the authorized users of the integrated information system eTracer, such as customers or employees
of the courier company, that have access to the eTracer service for object tracking have real-time access to
automatically updated and structured data regarding the time and location (geographical) information of objects
and are informed regarding the tracking and tracing status of their packages using common Web 2.0 enabled
browsers (IE, Firefox, Safari, Chrome, etc.).

3.2 Data Reduction Model
As described earlier, the semantic ‘uplifting’ process is computationally intensive. In order to restrict the
amount of data processed a data reduction model is proposed and followed. This model relies on the fact that
continuous location-update data do not need to be processed. A GPS device over a period of time can generate
a huge amount of points and a pre-processing is necessary in order to choose a representative subset of these
points before continuing with any further event extraction or visualization. The first step is to identify the area
that contains all the points and this can be done by computing the upper-left corner and the lower-right corner
of a virtual box that contains all raw data Then, this rectangular area is divided in \( M \times N \) rectangles of equal size.

In each smaller rectangle the convex hull of the contained points is computed as a convex polygon. For
implementation purposes the Gift Wrapping Algorithm has been used [10]. Afterwards, the points of the
convex polygon are used in order to compute the coordinates of the mean center point. In this way a
representative point is computed for every rectangular and all the GPS points are ultimately reduced to a
maximum number of \( M \times N \) representative points.

![Graphical representation](image)

Figure 2 (a) Reduction steps, (b) Data reduction for a specific grid, (c) Visualized post-processed result

The adapted Jarvis March Gift Wrapping Algorithm starts with \( i=0 \) and a known point \( p_0 \) to be on the
convex hull, e.g., the leftmost point, and finds the point \( p_{i+1} \) such that all the rest points appear to be on the right
of the line \((p_i, p_{i+1})\). This point may be obtained in \( O(n) \) time (where \( n \) is the number of points) by comparing
the polar angles (Figure 2 (a)) of all points with respect to point \( p_i \) taken as the centre of polar coordinates.
Letting \( i=i+1 \), and repeating until one reaches \( p_h= p_0 \) again yields the convex hull in \( h \) steps (where \( h \) is the
number of points on the convex hull). In Figure 2 (b) the blue points represent the original data from the GPS
device and the magenta points signify the representative data. Figure 2(c) shows the visualization result of a
reduced object trace.

Figure 3 illustrates the efficiency of the data reduction algorithm is. As depicted, the algorithm converges to
a certain amount of representative data which is dependent to the size of the grid.
4 Conclusion

In this paper we have presented an overview of eTracer; an end-to-end near real-time object tracking and tracing system. eTracer satisfies the need for a monitoring, detection and tracing system in the sector of transports of goods which is continuously increasing. The system faces many technological challenges such as the aggregation of many information sources and the computational intensiveness of post-processing data during the extraction of meaningful states out of raw data. The above challenges are effectively tackled by eTracer. In this work the analysis of the eTracer architecture has been provided. Special emphasis has been given in the data reduction model that was used in order to reduce the post-processing computational intensiveness. Moreover, eTracer was tested in a real-case environment using real field tests (i.e., Courier company). The design and implementation of the eTracer system (www.etracer.com.cy) was supported by the Cyprus Research Promotion Foundation (RPF) and co-funded by the European Regional Development Fund (ERDF).

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