Ameliorating Compound Logistics Processes using Virtual Geo-Sensors

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***Abstract*—A virtual Geo-Sensor is a software module with associated geo coordinates which recognizes the physical presence of traceable mobile devices within a distinct interaction radius. At spatial proximity of an authorized device the Geo-Sensor automatically triggers electronically controlled actions (e.g., it opens gates, starts or stops engines, etc.) not distracting its users from their focused task by making them press buttons or glimpse at a display. This basic paradigm can be adopted for improving logistics processes inside premises, e.g., for supporting the unloading task of trucks from various suppliers. At every unloading site within a closed compound a virtual Geo-Sensor recognizes the arrival of trucks, detects congestion and automatically initiates re-routing procedures which are relayed to the drivers via a network of mobile devices carried within the trucks. This paper sketches the principles and the architecture of virtual Geo-Sensors and demonstrates their potentials in logistics fields in the frame of an experimental survey at the MAN truck manufacturing site in Steyr, Austria.**

Keywords: Geo-Sensors; Compound Logistics

I. INTRODUCTION

The improvement of supply chain event management in logistics domains utilizing new tracking and tracing technologies has been recognized as a key aspect for modern location- and context-based services. The benefit of knowing the live-position of delivered consignment is apparent for supplier and customer enabling them to carry out precise and concerted (pre-)calculations on the event chain with a supposed positive impact in terms of processing time and costs [20][24].

The technical prerequisites for implementing such a service are no longer considered an obstacle, nowadays. It is more an issue in terms of organization, law and work councils when numerous involved suppliers should participate in a multilateral transparent delivery process outside company borders. However, the potentials in utilizing location-based information for logistics fields cannot only be found in time extrapolations for arriving freight from different suppliers. The potentials can also be exploited *within* compound borders where a passed transitional liability grants more legal freedom of action to the compound carrier.

In the course of the nationally funded research program AGTIL [19] focusing on adaptive value creation by the means of the integration of technological, sociological and logistical issues the project consortium consisting of the University of Linz, the Upper Austrian University of Applied Sciences (Logistikum) and MAN Nutzfahrzeuge (truck manufacturer) in Steyr, Austria, envision a mobile location-based compound logistics system for controlling and accelerating the unloading process of delivered consignment within yard borders.

The technical approach for the vision is based on the use of an existing location-based service for mobile devices developed in the course of a research-cooperation between the University of Linz, Siemens Corporate Technology and the Ars Electronica Futurelab. The service is called "Digital Graffiti" [16][18] and is considered a social communication-, collaboration-, and interaction platform where arbitrary users are capable of observing their "friends"' residences in near real-time (their revocable permission provided) and of consuming and placing location-bound information using their mobile phones. The novelty in this service is included in the type of information that can be placed: information does not only contain static data like text or pictures, it also encloses code fragments or triggers to external services which will automatically be executed when the appropriate privileged user reaches regional closeness to this information (virtual Geo-Sensor [17]).

Upon the technological core of Digital Graffiti the AGTIL project consortium has developed a service infrastructure for a mobile compound logistics system. The moving entities (trucks and their drivers) are identified and tracked by mobile devices. The cargo is modeled as a dynamic part of the driver's personal user profile enabling a clear mapping of freight, driver and truck. Individually adjustable access- and visibility privileges guarantee privacy protection on a technical basis leaving legal privacy concerns up to negotiations among the participating parties. The control mechanism in this system is built upon the Geo-Sensors placed at all unloading sites and at neuralgic positions along the compound road network automatically announcing e.g., the arrival of trucks and re-calculating site stopover sequences on delays.

II. RELATED WORK

The combination of methods, technology and available information of location-based services and the dynamics of logistics domains has been a focal point of investigation since the emergence of (mobile) tracking devices capable of wirelessly transmitting data [29][30][31]. Various publications present design issues for logistics systems considering location-, context-, and situation-awareness [21][22] for optimizing logistics processes through real-time vehicle routing and mobile technologies [23]. Many of them address the problem of cooperating different carriers within the supply chain and offer mathematical solutions based on location-bound information. They hardly address closed logistics optimizations based on mobile platforms within compound barriers.

Considering the technical basis of our proposed service (the Digital Graffiti system) we realize location-based services as an emerging focal point of investigation for an increasing number of research labs and industry [5][6][14][15][27][28]. LocatioNet [9], Mobiloco [10], Plazes [12] or Socialight [13] are services for mobile phones that enable users to get in touch with friends and/or mark real physical locations with simple electronic tags. A comparable application is Google Latitude [4] connecting users to their friends and their current place of residence and providing location-based information within a virtual global public information space.

The concept of the Geo-Sensor handles the issue of seamless transitions between the real and the digital world [11] without distracting the user's attention [7]. Modern solution approaches use Near Field Communication (NFC) [25][26] for contactless initiated actions following the same objectives of dismissing the conventional display and key-controlled interaction paradigm in order to claim a minimum of attention for performing an action at a place of event (e.g. SkiData – contactless access control in skiing areas through RFID). However, the disadvantage in this solution lies within the fact that every location which is supposed to trigger an electronic action has to consider mandatory structural measures for engaging the NFC principle. Beyond, a remaining part of attention is still required as users are supposed to know the position of the NFC system and bring up the RFID tag or reader (depending on which part of the components carries the reading unit) close to the system for proper detection. Regarding the structural measures for implementing NFC this technology is only marginally applicable causing financial and environmental impairments.

Spontaneous interaction triggered upon physical proximity was further studied in numerous works [1][2][8]. These approaches share the aspect that radio sensors are used to determine mutual proximity between smart artifacts and humans. The simplest form of smart artifacts are Smart-Its [3], small computing devices that can be attached unobtrusively to arbitrary physical objects in order to empower these with processing, context-awareness and communication. Smart-Its are designed for ad hoc data exchange among themselves in spatial proximity. Gellersen et al. [3] underlined the importance of awareness of the environment and of the situation for inferring behavior of mobile entities.

III. ARCHITECTURE

Digital Graffiti as the technological basis is conceived as a platform to manage and visualize location-based information within the context of a mobile user. It is built upon a flexible network of mobile GPS-enabled devices (i.e., mobile phones, PDAs, netbooks, etc.) wirelessly obtaining and storing location-based information from and to a central server system (see Figure 1).

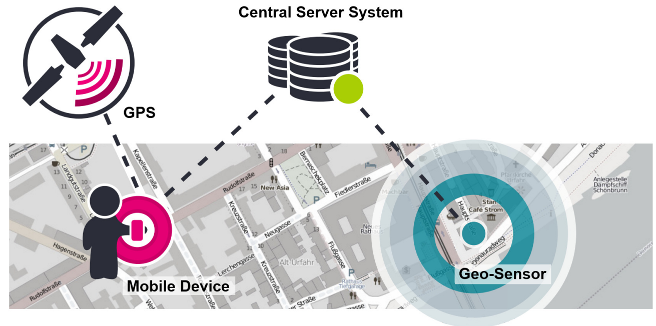

Figure 1. Digital Graffiti System Components.

It has been enhanced with functionality to fulfill the demands for a social network, comprises a map server (e.g., for custom floor plans or industry areas), provides an elaborated user and privileges management concept and additionally handles chat messaging and communication encryption for secure data transfer.

The clients are supposed to be executed on any mobile platform either as a native application particularly designed for the device (currently available for iOS, Android, Symbian and Windows) or as a web application (utilizing the novel W3C standard and HTML5 for accessing GPS out of a browser and complying with the requirements of a bare device without the needs of installing client software).

Once registered and logged in, the user is visualized as an avatar at his exact residing position in front of a map (see Figure 2) and his geographical position is textually resolved into a human readable address (e.g., building names, floor descriptions or office numbers). Alongside user's own position the system also offers to track the position of the user's friends, provided that the respective friend has granted permission. To sustain privacy this permission can be revoked by one click in the user interface.

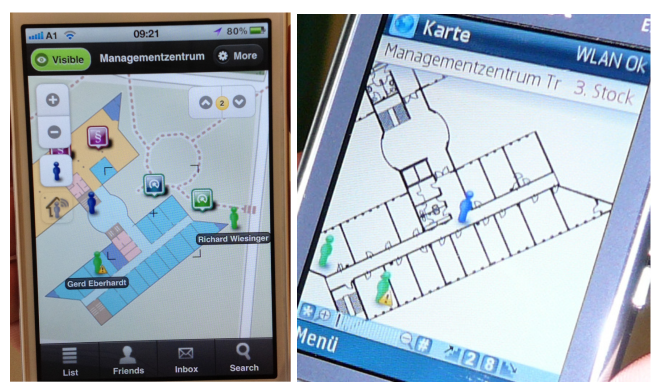

Figure 2. Digital Graffiti User Interface.

Similar to conventional cellular telephony the system uses a distributed provider model for the server-side component where users all over the world can join the provider of their choice in order to take part in the mobile location-based information service. This proven model distributes the load from (asynchronously) communicating users and guarantees scalability of the service all over the world as each provider only handles a limited number of clients.

Every provider stores a set of geographically linked information in appropriate fast traversable geo-data structures (e.g., r-trees) containing hierarchically combinable content modules (which we call gadgets) for text, pictures videos, sound, etc. The name gadget already refers to a possible activity within a module and is the key for a generic approach of integrating arbitrary system connections or electronic actions to be triggered automatically on arriving users (Geo-Sensors). They provide the basis for extensibility to third-party systems for which the number and variety of electronic connections is unforeseeable and simultaneously enriches the potentials of such a service [18]. Figure 3 illustrates the common principles of the Geo-Sensor architecture which enables fast connections to third party systems:

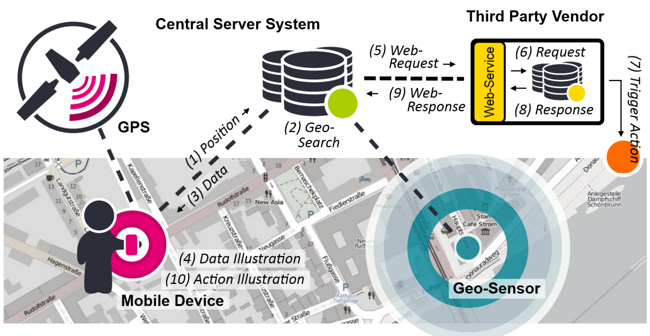

Figure 3. Geo-Sensor Architecture.

Clients repetitively transmit their own (commonly GPS-based) position to a server (1), which evaluates the geo-data considering visibility radiuses and access constraints (2) and transmits the corresponding results back to the clients (3). Generally, when the transmitted information contains conventional gadgets as text and pictures, it is immediately displayed on the output device of the client (4). The basic idea for executing code is to use the gadget metaphor and store executable code inside instead of text or binary picture data (smart gadgets). Therefore, we propose a web-service-based mechanism which is both effective and simple to extend: Smart gadgets contain a simple URL or XML-based web-request to a remote web-service which is the actual component to execute the code. When a client receives information containing a smart gadget, its URL is resolved (5) which is handled internally (6) and finally triggers the desired action at the third-party vendor (7). A response back to the client (8, 9) can additionally be illustrated as a visual confirmation whether the action could have been executed or not (10).

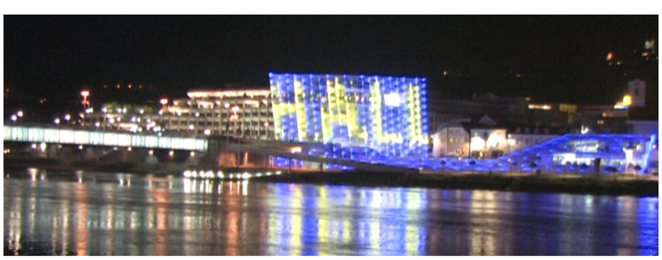

Figure 4. Geo-Sensor Example using Digital Graffiti.

This approach is simple because the clients just have to handle standardized web-requests. A majority of currently utilized mobile platforms support these mechanisms. Important for third-party vendors: Their internal data representations, servers and control units are hidden from the publically accessible location-based service guaranteeing a maximum degree of data security for the vendors.

Figure 4 gives an impression on this innovative interaction paradigm: We have put a Geo-Sensor containing executable code near the Ars Electronica Center building in Linz, the LED-facade of which is capable of displaying marquee text running around the walls of the building. An authorized person approaching the Geo-Sensor automatically triggers the execution of the contained code which causes the facade to welcome the user personally. Of course, this application is more of a playful approach rather than a business scenario, however, it demonstrates the potentials of the service enabling its users to initiate any electronically controllable action just by their physical presence.

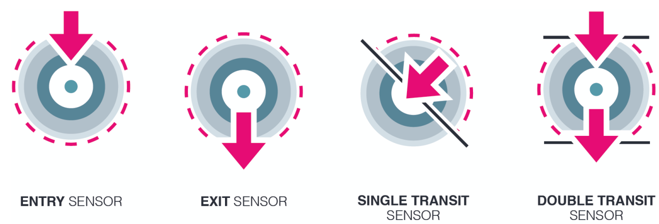

Figure 5. Geo-Sensor Types.

For even more flexibility the Digital Graffiti framework provides a series of differently triggering Geo-Sensors (see Figure 5) an application can select from in order to meet its particular requirements best possible: The simplest forms are Entry- and Exit-Sensors firing when a device either comes into or leaves the interaction radius of the sensor. A Single-Transit-Sensor defines a virtual line within its radius which must be passed from one direction in order to trigger it. Sensors of this type may be used in traffic scenarios where just the flow of a distinct direction is of interest. An extension of this sensor is the Double-Transit-Sensor firing twice at the entry and exit of a device from a given direction. Sensors of this type may e.g., detect congestion.

IV. Experimental Survey

A Double-Transit-Sensor also recognizes the stopping times of every truck in the course of an experimental survey at the MAN truck manufacturing site in Steyr, Austria, where the unloading process of consignment should be ameliorated within compound borders using the location-based Digital Graffiti service. At every unloading site such a sensor both records arriving as well as the departure times and reports potential congestion to a control center where re-routing procedures can be initiated for further trucks scheduled for a congested site. Re-routing can both be done manually due to a visual impression of capacity utilization on the compound or automatically considering dynamically adjustable constraints like unloading sequences.

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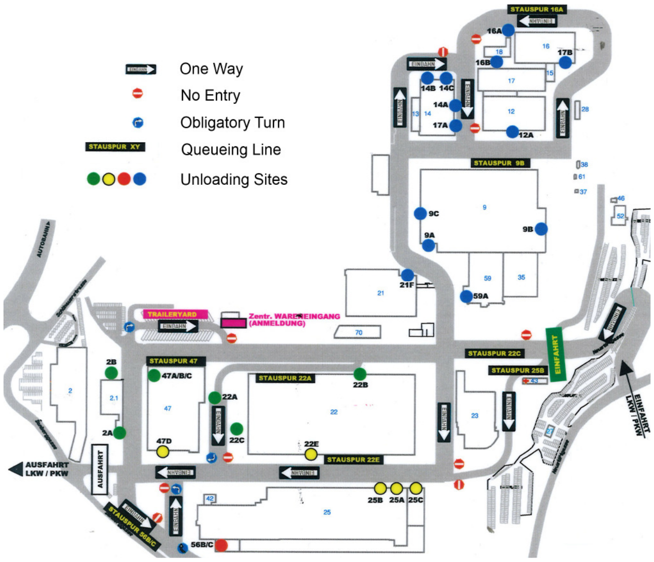

Figure 6. Geo-Sensors at 25 Unloading Sites at MAN Steyr.

Figure 6 gives an impression on the setup of the survey with in total 25 Double-Transit-Sensors at unloading sites (marked by green, yellow, red and blue dots) and several other Geo-Sensors at strategic points in the compound (e.g., at the two main entries or at the trailer yard where arriving drivers have to register and deposit their papers.

The test scenario works as follows: When the driver arrives at the trailer yard he is handed out a mobile device clearly identifying the truck and its cargo. A preceding registration click has been carried out by the operator connecting cargo data and device. Now the device provides tracking information to the control center and informs the drivers about the succeeding unloading site. At changes the operator is able to address an alternative destination directly to the appropriate driver and is therefore given a powerful instrument to dynamically interfere into compound processes.

The system architecture for this experimental survey (see Figure 7) contains an original unchanged Digital Graffiti kernel managing mobile users and Geo-Sensors (i.e., LBS data). It is controlled by a wrapping web-based Control Center, the actual application core handling unloading sequences or re-routing procedures. Proprietary cargo data (hosted at a special server system at MAN) is transferred via EDI (Electronic Data Interchange) interfaces to a temporary OFTP-server from where it is pushed to the Control Center.

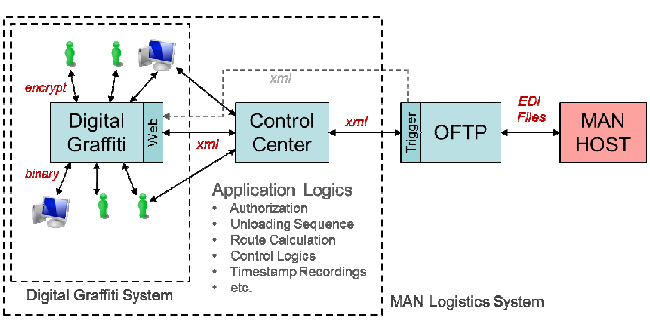

Figure 7. System Architecture of Experimental Survey at MAN Steyr.

Figure 8. Compound System: Driver's Client.

Figure 8 shows the prototype mobile client application for the drivers (here: running on a Samsung 7" tablet with Android 2.2 mounted inside the windshield of a truck) which indicates the driver's own position on a detailed compound map, his next goal (here: unloading site "22E") and the route to it.

In the first test phase the technical requirements concerning feasibility, accuracy and real-time behavior have been evaluated: Is the compound system using Geo-Sensors capable and accurate enough to recognize waiting times in appropriate time intervals? Therefore, a number of selected trucks have carried mobile devices during their regular unloading process. The Geo-Sensors at the unloading sites have recorded all timestamps regarding entry- and exit times which have been cross-checked by manually noted timestamps of accompanying supervising persons.

As the assessment of this technical precondition succeeded (i.e., there is a clear correspondence between manually and automatically recorded timestamps) the second test phase could be initiated evaluating the economic potentials concerning time savings. In its final state this survey phase schedules for a compound-wide test with mobile devices in every truck and an automatic re-routing process due to detected delays. As such a test scenario is both expensive and organizationally elaborate (about 150 trucks arrive at the compound during the day with a maximum number of 40 trucks residing concurrently inside premises) only a light-weight version of this test has been carried out at this time of writing with an assortment of both manually and automatically recorded timestamps and a manual interference of an expert operator due to visually recognized impairments in the speed of the unloading processes. However, these data already reveal the economic potentials of this system in terms of reducing stopover times for individual trucks.

V. PRELIMINARY RESULTS

Figure 9 illustrates a glimpse on these data showing preliminary results of the system tests. The picture lists operating times for one specific test day on November 22^{nd} 2011 at seven unloading sites (named "22A", "22B", "56", etc.) at the yard of MAN Steyr for 71 trucks and 112 unloading tasks performed by these trucks. So, the picture presents time measurements on site level, not for individual trucks (i.e., several trucks are listed more than once in this picture).

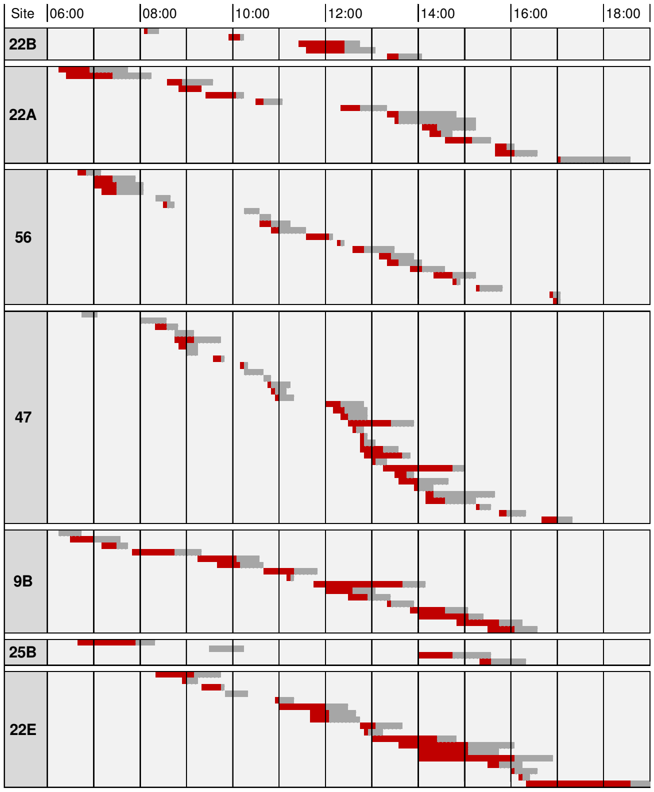

Figure 9. Recorded Timestamps at Unloading Sites.

The red lines indicate waiting times and the gray lines the time for the unloading process itself. In total figures this means that the drivers spend 45.6 hours waiting and 50.7 hours for the unloading tasks (or: approx. 25 minutes at every site for each driver waiting and half an hour unloading), which reveals nearly half of the time spent waiting. Thus, the theoretical potential considering these figures is an average reduction of unloading times by half.

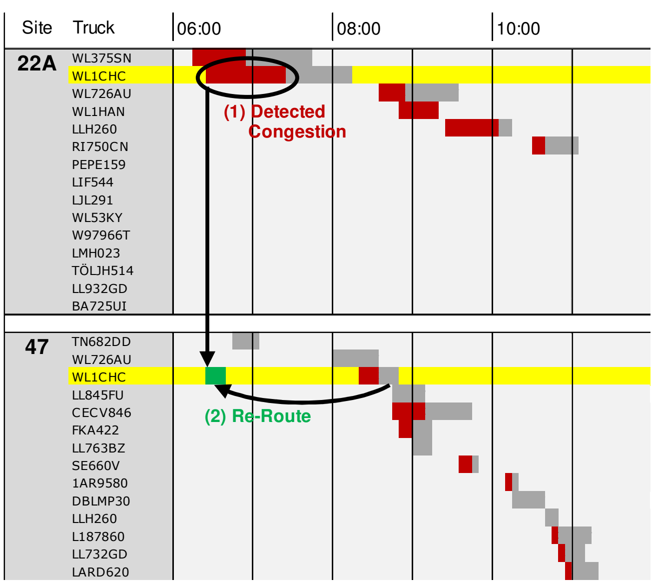

Figure 10. Re-Routing due to Congestion.

A closer look on the figures shows (see Figure 10) that the truck marked in yellow faces congestion at site 22A, whereas site 47 would be clear at the same time. It could be rerouted in order to switch the unloading sequence (assuming that the order is variable what might not always be the case) and in addition avoid a second recorded congestion later at site 47. This example results in a time improvement of 40% for this individual truck (before: 75 min waiting time, after: 45 min) and impressively demonstrates the potentials. However, it is still an excerpt for one individual entity and does not consider side effects which will likely occur on re-routing instructions, thus only an area-wide test which is still to be conducted will provide a clearer insight into the contingent average value of improvement.

The tests have also provided valuable information concerning social issues: Whereas drivers unaware of the regional conditions embrace a mobile guide escorting them through the compound there are more than half of the drivers who repetitively come along and refuse an additional gadget providing them with information they know anyway.

Figure 11. User-Interface Adaptations.

As a consequence, we have modified the user interface for the mobile device in a way that it does not show a map with one's own position on it, anymore. Instead, we utilize the local direction signs and appropriately display them on the screen (see Figure 11). Drivers unfamiliar with the place are still guided by the system whereas the others may keep their devices in their pockets (not perceiving well-known information) but are also notified on re-routings by an acoustic alarm and a firm depiction of the change.

VI. Conclusion and Future Work

Although, the system presented in this paper is still under development first prototypical implementations and tests confirm applicability of the virtual Geo-Sensor metaphor for being used for closed compound logistics operations. The project consortium is convinced that Geo-Sensors offer large potentials in terms of reducing congestion times while carrying out in-yard tasks. At every unloading site a virtual Geo-Sensor detects the presence of trucks and automatically notifies and re-routes on delays.

For verifying the supposed economic potentials further tests within the compound of MAN in Steyr are still necessary. Every truck driver will have to carry a mobile device and is requested to follow re-routing instructions relayed by the mobile device in order to create a quantifiable statement considering side effects of this dynamic interference. The final goal will be a downloadable mobile app to be installed by the participating parties in order to avoid registration routines at the entry gates with benefits for both sides regarding an improved use of their resources.

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