

# LIAISON ToD: An Intelligent Location-Based Taxi Hailing System

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**Abstract** — FP6 IST-511766 LIAISON Integrated Project federates an EU pole of excellence committed to build commercial Location Based solutions, targeting mobile professionals, also applicable to the mass market. One of the 6 scenarios considered in LIAISON, targets an automated taxi booking, dispatching, and monitoring application, effectively addressing current taxi sector needs, and potentially expanding to emerging car-pooling / sharing models, allowing integration between modes of transport in urban / densely populated environments.

**Index Terms** — FP6 IST LIAISON, Taxi on Demand, Location Based Services Platform, Location Based Ad-hoc Groups & Dispatching.

## I. INTRODUCTION

THE LIAISON Integrated Project (FP6 IST-511766, <http://liaison.newapplication.it>) is a 42-month project co-funded by the European Commission under the 6<sup>th</sup> Framework Programme and led by Alcatel Alenia Space. LIAISON aims at providing end-to-end solutions for a wide range of professional environments, by combining existing standards and techniques with innovations resulting from EGNOS [1] and GALILEO [2], as well as capabilities of existing / emerging mobile networks (2G, 3G, TETRA, and WLAN).

Realized through a user-driven approach [3], the LIAISON solution addresses the potential needs of EU mobile worker environments, corresponding to 6 operational scenarios, and representing a wider range of EU mobile work-force segments: Incident Management (IM), Fire Brigade (FB), Electricity Grid / TV Network (e-Maintenance - eM), Urban Waste Data Collection (WDC), Taxi on Demand booking & dispatching (ToD), and Security personnel (Lone Worker - LW).

LIAISON aims to bring consistent recommendations for the harmonization of labor legislation in Europe, contributing to the fulfillment of the E112 [4] directive and promoting the

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usage of EU space infrastructure.

In the above context, the ToD test-case aims to integrate and customize the LIAISON architecture into an automated taxi booking, dispatching and monitoring paradigm, and deploy a pilot in Athens, Greece, demonstrating a number of features including Location Based Ad-hoc Grouping & Dispatching (LBAG), multi-lingual presentation (MP) and request transcription (RTS), tracking for customised mappings & 3D settings, elevated 2D graphical I/Fs (e2D), route navigation / guidance with traffic hints, customised charging & billing (CAB), and automated emergency calls over TETRA.

Automated taxi hailing / booking applications are currently emerging, along with fleet management systems, following the wide adoption of GPS and GIS technologies.

The ToD design, implementation and demonstration is led by institute NCSR “Demokritos” IIT, and supported by Taxi cooperative / dispatcher EDMC, network operators Vodafone (GPRS/UMTS) and OTE (TETRA), GIS providers FORTH institute and Navteq, and the rest of the LIAISON consortium.

This paper is structured as follows: Taxi market background providing trends, drivers and requirements for the ToD application are presented in section II, based on the LIAISON market study and SWOT analysis [5]. Then in section III ToD overview and decomposition into major functionalities is provided and discussed, focusing on ToD specific aspects, such as location-based booking management (LBAG). The generic LIAISON architecture customized for ToD is presented in the sequel in section IV. Finally conclusions are drawn related to the advantages and potential of the system, and possible extensions in both technical and business context are briefly discussed in section V.

## II. TOD MARKET BACKGROUND & DRIVERS

The taxi sector in the EU is highly diversified concerning the types of enterprises, number of taxi licenses, variety of tariffs and drivers’ qualifications. However, one common denominator in major EU countries is a strictly regulated taxi market. Contrary to the North of Europe, tariffs are fixed by law in most EU countries, thus limiting taxi companies’ potential to acquire price sensitive customers. Fixed tariff policies are thus considered as a driver for investing in new systems providing a broader range of services and a higher quality for attracting new customers.

Market study and SWOT analysis [5] carried-out in the context of LIAISON, showed that the taxi market is facing

increasing costs (fuel consumption due to traffic congestion, increasing petrol/gas prices, vehicle maintenance, etc) and decreasing margins. As a consequence, more taxi owners (freelancers) and companies join radio dispatch centres, seeking business stabilization and/or augmentation. Dispatchers on the other hand, look for automated solutions to reduce co-ordination effort and increase efficiency and capacity to control larger fleets. There is also an increasing trend for high quality services addressing the needs of important niche markets (executive / VIPs, hotels, etc). Private hire (PHV) services represent today the most prominent sector related to the taxi market.

Current GPS-based solutions for taxi dispatching and fleet management, penetrate the market via promotion of major dispatch centres, with installation / maintenance cost, and taxation being the critical adoption factors. Therefore solutions such as the LIAISON ToD should in principle target large taxi fleets (>150 vehicles) in major cities, that can afford the cost of an integrated and full-featured system. Small taxi companies or freelance drivers do not often see the need of, or are unaware of solutions based on new technologies. This however is subject to change, considering the overall evolution in the automotive industry.

On the other hand, the car industry is now looking at a number of both critical (e.g. break-down support) and non-critical applications (e.g. car to car service roaming / communication<sup>1</sup>) that require location accuracy and speed at the levels that GALILEO promises to deliver. Such features will catalyze consumers' decisions in the coming years, when the overwhelming majority of newly manufactured cars will feature navigation and infotainment equipment. Users in the near future will be discovering Points Of Interest (PoIs) through their mobile devices and expect their vehicles to provide clever routing and accurate navigation to their selected PoIs. In such an environment, it shall be hard for taxi professionals to keep a sustainable business, based only on traditional street "knowledge", or systems that do not provide features up to their customers' expectations.

To sum up, the willingness of the taxi sector to embrace innovation and investigate new ways of value generation is strengthening<sup>2</sup>. Drivers look for increased safety and efficiency, while technology and content providers teaming with major taxi market stakeholders will not hesitate to invest on novel solutions, once their business will increasingly rely on quality and efficiency. This is especially true for certain niche segments in the high end of the market. The taxi user in LIAISON (EDMC) is an example of such an early adopter [3].

<sup>1</sup> E.g. see <http://www.car-2-car.org/>, a consortium built by 6 major EU car manufacturers, with the goal to create a European industrial standard for car communication spanning all brands.

<sup>2</sup> E.g., Taxi Stockholm controlling 150.000 cabs via a GPS-based voice-automated discovery and dispatch service, routes more than 44% of their calls automatically, and has already acquired more than 60% of the local market – no small feat considering 21 competing local companies.

### III. TOD FUNCTIONAL DECOMPOSITION

From a functional architecture perspective, the ToD system ([8]) provides transparent booking, dispatching and tracking for navigation and security over public cellular networks, with an intelligent dispatching centre (RCC/EIS) hosting the LIAISON Platform capabilities [6]. The following figure illustrates an overview of the ToD system functionalities:

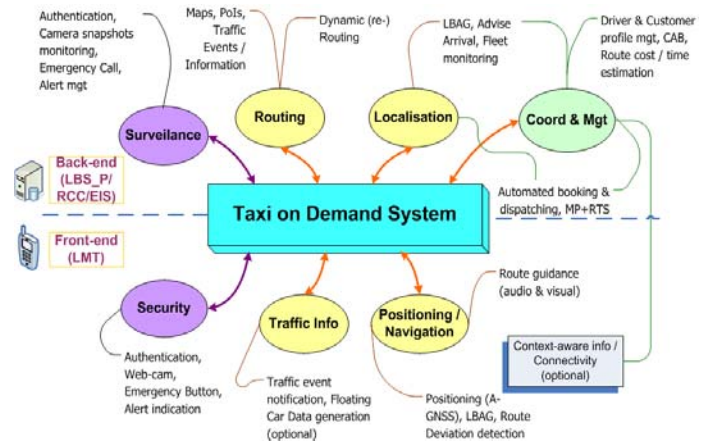


Figure 1: Taxi-on-Demand (ToD) Functional Overview

Functionalities in the above schema, are grouped as:

- ❑ Back-end functions, residing at the Operations Centre (RCC/EIS/LBS\_P) include: Surveillance, Routing, Localisation, and Coordination & Management (COMA).
- ❑ Front-end functions, residing in the vehicle (LIAISON Mobile Terminal - LMT) include: Security, Traffic-Info, Positioning & Navigation, and context-aware information.

In the sequel, the aforementioned functionalities are outlined.

#### A. Surveillance / Security

The mission of these functions is to provide real-time passive protection and monitoring of the mobile worker, covering 100% of the dedicated work area, and being available on a 24-hour basis. Surveillance provides operations monitoring, including all data exchange between the vehicle and the Operations Centre. An elementary level of security support is provided via the authentication procedures of the system for all interacting actors, i.e. drivers, passengers, and human operators in RCC/EIS. Moreover, the LMT integrates an advanced alarm function to be used for particular emergency cases, allowing for instant delivery of position and other relevant information to the Operations Centre. The alarm function is activated automatically (upon generation of a security alert e.g. car-crash), or manually via the external (concealed) emergency button in the proximity of the driver. A web-camera appropriately installed in the vehicle is also activated in such cases, for the provision of car-interior snapshots send automatically (with prior driver consent) to the RCC. Both the Operations Centre and the LMT are able to automatically establish a voice communication (via TETRA voice bearers) between human operator and driver, or to a public emergency service point in the event of a security alert.

## B. Localisation / Routing / Traffic / Navigation

The principle task of this function group is the geographic positioning and tracking of the mobile worker while operating on location, obtained with the help of the LMT. Localisation is interoperable with COMA regarding the tracking of taxis, transmission, and visualization of location information within the context of operational requests. Routing, route update, and navigation utilize traffic hints provided to the system via an external source [7], and integrate an additional layer of traffic-related events on top of standard GIS information. These core functionalities of the LIAISON system are implemented in the Location Based Services Platform (LBS\_P) server [6]. In addition, ToD-specific functionalities related to location based booking are implemented via LBAG [11], i.e. a mechanism addressing two principal problems, related to centralized systems and freelance drivers:

In the centralised case, the operator (dispatcher) broadcasts booking requests to all taxi drivers and waits for responses. This in effect floods the network with requests sent even to taxi drivers who are known NOT to be able to serve it for different reasons (already booked, too far, etc). The LBAG mechanism enables notification of only those taxis that are most likely / appropriate to undertake the booking, based mainly on proximity to pick-up point, bid time and other criteria (e.g. customer preferences, dispatcher policies, etc).

In the peer-to-peer case the LBAG mechanism publishes requests from customers only to taxis in an appropriately prescribed geographical area (ad-hoc group), which again results in optimizing network traffic. After accepting the request the taxi driver is able to directly communicate with the passenger, to e.g. provide booking confirmation (acceptance of request, provision of estimated route cost) and notify when the taxi is approaching the customer (advice arrival).

LBAG is implemented as a network-agnostic mechanism, thus providing a portable, cross-platform application tier where virtual groups of drivers are formed based on location data and possibly other criteria. Group membership is updated as taxis move in and out of areas defined in a static (fixed topology), or dynamic manner (area shaping on-the-fly based on booking requests distribution). The introduction and evaluation of LBAG may lead to an extended Peer-to-Peer paradigm, for building similar applications without the need of a “handshaking” entity between service provider (taxi-driver) and service consumer (passenger). A possible extension of this concept is the use of LBAG for discovering other customers of the service that are currently in the area, and would be willing to share (part of) the ride. It thus acts as a car pooling mechanism, for maximizing vehicle utilization in urban environments.

Floating Car Data (FCD) generation<sup>3</sup> relates to strong market requirement for nRT (near-Real Time) traffic (and other GIS) information. Taxis, being heavily-used vehicles are best-suited for providing information derived from their

<sup>3</sup> Although potentially supported by the system, FCD is currently out of the scope of the ToD TC pilot and demonstration.

movement and their whereabouts, to GIS providers, radio stations, local authorities, etc.

## C. Coordination & Management (COMA)

This function provides real-time monitoring and operational support for the taxi drivers including:

- Operations / Booking resources Management
- Routing (mainly estimations<sup>4</sup> of route cost and time)
- Data acquisition (driver and customer profile management)
- Safety purposes (emergency calls, car-interior monitoring)
- Worker status (position, statistics, operational capability)

COMA has to be interoperable with both “Surveillance” and “Localisation / Routing” functions. The management sub-system encompasses an application layer integrating the LMT with the Operations Centre. It contains several DBs with possible integration (as being beyond the scope of this project) with other external ERP systems, e.g. for billing and accounting, complex planning and optimisation tools.

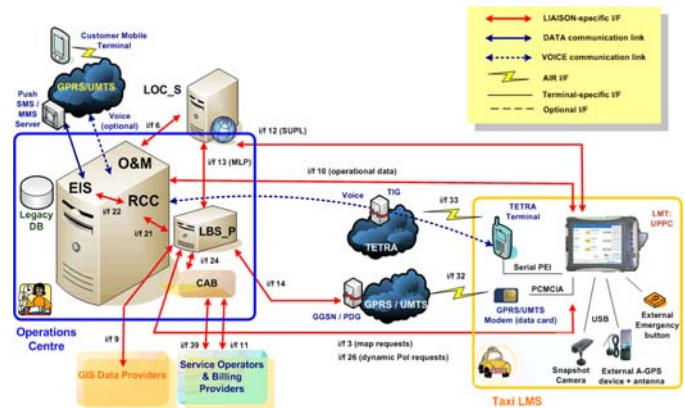
The Operations Centre is able to assign priority levels and status to incoming and existing events and allow management of customised event displays. Priority assignment is currently predefined at configuration time and not handled dynamically.

## D. Context Aware info / connectivity

This functionality is an optional component, relating to the acquisition / automated reception of content relevant to the vehicle location (e.g. local infotainment, advertisement, etc). Although potentially supported by the system, context-aware content is currently out of the scope of the ToD TC pilot and demonstration.

## IV. ToD ARCHITECTURE

An overview of the ToD system physical configuration<sup>5</sup> is illustrated in **Figure 2**.



**Figure 2: ToD high-level architecture and LIAISON I/Fs**

ToD solution consists of the following physical components:

<sup>4</sup> The Operations Centre shall have at its disposal a list of fares associated with certain routes (e.g. routes of greater demand), used instead of calculated when the passenger request coincides with any of these routes.

<sup>5</sup> As design and implementation are still active, at the moment of writing this paper, certain features of the system may, or may not be available for demonstration, depending on technical and budget restrictions.



- **Operations Centre server** hosting the following functionalities (corresponding to LIAISON subsystems):
  - **EIS:** The Enterprise Information System links the ToD system to the EDMC legacy DB providing a front-end to the ToD customer for registration and booking. Driver profiles and tariffs, i.e. data relating to dispatcher main business will reside in the RCC Customised Module. In ToD, the EIS box hosts the web service which handles customer profiles and orders.
  - **O&M:** Operation & Maintenance box hosts management functions relating to the operation of the ToD application and all supporting S/W and H/W.
  - **RCC:** The Remote Control Centre is the central control component of the system, involving all intelligence and resource handling for the ToD application. RCC hosts most of the functions that correspond to a traditional dispatch centre (fleet and booking management) plus new functionality such as Location Based Ad-hoc Groups (LBAG), Multi-lingual Presentation (MP) and Request Transcription Service (RTS).
  - **LBS\_P:** : the LBS Platform containing the ToD demo (Attica) area Maps and the relevant no-turn, direction, and PoI information also resides on the Operations Centre. Its main task is routing / navigation (with traffic hints) / tracking and geo-coding data provision.
  - **CAB:** The Charging Accounting and Billing component of ToD also resides in the Operations Centre. Its main task is to collect charging records related to network transport and ToD system use, and bills from content / service providers. The taxi drivers are then invoiced (one-stop-billing) for their use of the communication network, GIS content and LIAISON services (LBS\_P / LOC\_S use).
- **Call centre** at the RCC provides vocal access to the taxi fleet over a TETRA network. Voice communication between the Operations Centre (RCC) and the taxi driver is assumed via the connection of OTEs TETRA Infrastructure (Telephony Gateway - TIG).
- **Location Server (LOC\_S)** hosting A-GNSS positioning, is the source of location information (A-GPS) for all ToD subsystems.
- **GPRS (/UMTS) Infrastructure** represents the cellular data bearers (TCP/IP and SMS/MMS messaging) provided to the ToD system for RCC – LMT data communication.
- **GIS Data Providers** provide maps and traffic information updating the LBS\_P.
- **Service Operators and Billing Providers**, effectively represent all business actors providing services to ToD. Currently the assumption is that network providers use their legacy billing systems to charge both passenger and driver. The driver charges the passenger and pays a subscription to the dispatcher. Location and GIS costs are aggregated into this bill, thus the dispatcher can provide a one-off charge to the drivers. The passenger (EDMC business is in the executive market segment) may also pay

a small subscription to the Mobile Operator, on top of communication costs for using the ToD service.

- **LIAISON Mobile System (taxi)**, is implementing the LIAISON system in the taxi, and comprises of the following components:
  - LMT terminal (Ultra-Portable PC) hosting the ToD specific S/W (ToD Customised Module). An emergency button (USB HID foot switch) is attached to the LMT.
  - LMT device is complemented with an external GPS receiver + antenna appropriately mounted on the vehicle.
  - GPRS/3G Data modem (PCMCIA card) for supporting data communications.
  - TETRA terminal (Motorola MTH650) providing the air connectivity with OTE's TETRA network.
  - In-car web camera (remotely connected to the LMT) for surveillance and emergency support.

## V. CONCLUSIONS AND EXTENSIONS

The taxi market faces ongoing changes. The volume of traffic is increasing dramatically, the costs for fuel are higher than ever, leading to increased costs and decreasing margins for taxi companies. This entails the necessity to implement new solutions to reduce costs and enable new revenue streams. Current solutions such as the ones deployed in Singapore [9], and London [10], provide taxi hailing based on the nearest coordinate method (taxi to pickup point), involving mainly SMS messaging for customer notification. ToD on the other hand provides a traffic-sensing based approach, integrating a wide range of features relevant to a number of professional market sectors (regular Taxis, Private Hire Vehicles, Hotel / medical / executive transport, traveling salesmen, etc) that seem eager to adopt innovation as an advantage in an upcoming landscape where competition will be on the range and quality of in-car Value-Added-Services. Functional features, resulting from comprehensive requirements analysis [3] and design [6] in LIAISON, equip the ToD solution with important advantages:

- The system improves operational efficiency by decreasing response times, thus enabling cost and time reductions. Benefits accrue to taxi fleet owners and operators, taxi drivers and customers. Faster automated dispatch processes lead to increased fleet management capacity and OPEX reduction for the dispatcher, while reduced pick-up time enhances customer satisfaction. The system ensures fairness to drivers and diverse policy options to operators.
- Route guidance addresses credibility issues by providing for increased transparency with regard to the chosen route. nRT traffic information integrated in ToD enables choice of the faster (not necessarily shorter) route, thus saving time, money, and fuel consumption (pollution relief).
- Taxi drivers are increasingly faced with violent assaults. Surveillance and advanced security (concealed button, alerts, camera, etc) features in ToD essentially improve

the safety for both the taxi drivers and customers. Besides violent assaults, the system also delivers additional safety in case of accidents, or other emergencies. In such events, police or ambulance vehicles may be immediately dispatched to the exact location of the incident.

- Facilities such as profile-based booking, emergency features, and peer-to-peer data communication between customer and driver, are beneficial to customers with special needs including disabled, elderly, etc.
- Location aware infotainment provided in the taxi provides an additional revenue potential for taxi drivers. Internet connectivity, mobile office facilities, multi-lingual support, tourist / shopping PoIs, and e-payment facilities are just some examples of a broad portfolio of services that are of interest to the high-end customer segments.

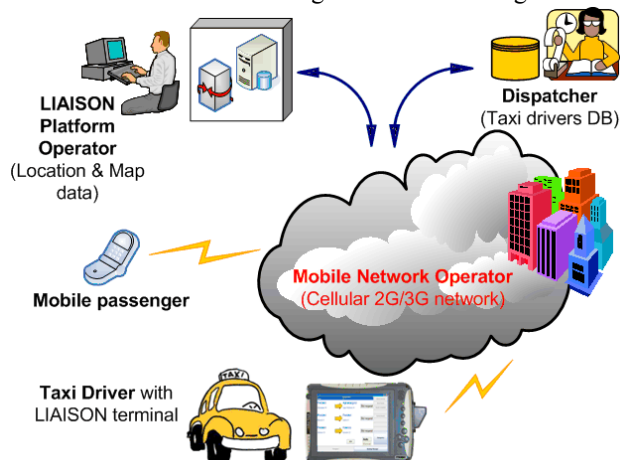


Figure 3: Peer-to-peer Taxi hailing actors

In addition to the above considerations, a new business paradigm is enabled by technologies such as the LBAG, providing peer-to-peer service order and delivery, with a minimum of centralized functionality. A lightweight version of ToD focused on LBAG for receiving booking hints and participating to booking bids, would be an interesting alternative to the subscriptions required by major dispatchers today (~ €100 monthly), provided that an entity with a strong market presence hosts CR and support. If the cost of dispatching would decrease thus lowering the entry barrier, then business opportunities for existing and new players would be created. Taxi drivers themselves becoming more familiar with in-car solutions, would seek solutions outside the traditional dispatcher-based structure. Brand names and especially Network Operators, Value-Added Service Providers (VASPs), and content providers could benefit by entering this new “booking transport” market. **Figure 3** illustrates the main value chain actors in such a scenario.

Automatic collection of traffic information and feeding to DBs (FCD) is another possible revenue generator for taxi professionals, and relates to the strong market need for nRT traffic info, following the evolution of traffic control / monitoring systems. ToD solution with FCD extensions could thus be used in road-charging schemes, or transport control

systems, supporting dynamic traffic monitoring & scheduling.

Last but not least, the ToD paradigm may be useful in aiding integration into mass transport, i.e. taxis filling the gaps between public transport service points, in a dynamic (peer-to-peer hailing) and/or coordinated (via operations / dispatch centre) manner. In densely populated urban environments, shared rides with taxis could be the precursor to generalized car-pooling (sharing) application, that promotes environmental objectives, while at the same time lowers costs (e.g. economies of scale in commuting) and enables novel business models.

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