Proceedings of the
2007 IEEE Intelligent Vehicles Symposium
Istanbul, Turkey, June 13-15, 2007

ToD: An Intelligent Location-Based Transport Management System

Panos I. Philippopoulos, Giorgos Soulos, Artur Krukowski, Nikos Argyreas, Vangelis Gorgas, Dimitrios Kyriazanos, Dimitrios I. Axiotis, and Stelios C. A. Thomopoulos[1]
Institute of Informatics & Telecommunications, National Center for Scientific Research "Demokritos"
[1]*email*: scat@iit.demokritos.gr

***Abstract*— In this paper we present a novel Taxi on Demand (ToD) management system that implements a location based and traffic-sensing approach and incorporates automated taxi booking, dispatching, and monitoring application. ToD solution effectively addresses current taxi sector needs, and could be potentially expanded to emerging car-pooling / sharing models, allowing integration between modes of transport in urban / densely populated environments.**

I. Introduction

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.

Automated taxi hailing / booking applications are currently emerging, along with fleet management systems, following the wide adoption of GPS and GIS technologies. Current solutions such as the ones deployed in Singapore [9], and London [10], provide automated taxi hailing based on the nearest coordinate method (taxi to customer pickup point), involving mainly SMS messaging for customer notification. In this paper, we present a system (Taxi On Demand - ToD) that provides a traffic-sensing and location 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).

ToD is developed in the context of the FP6 LIAISON Integrated Project [13] (http://www.liaison-project.eu), a 42-month project co-funded by the European Commission under the 6th Framework Programme 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], and capabilities of existing mobile networks (GPRS, UMTS, TETRA, 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 (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 usage of EU space infrastructure.

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.

The ToD design, implementation and demonstration is led by institute NCSR "Demokritos" IIT, and supported by Taxi cooperative / dispatcher EDMC, network operators Vodafone and Greek ex-incumbent OTE, 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 centers, 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[1]) 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[2]. 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) mainly serving enterprise customers and VIPs is an example of such an early adopter [3].

[1] 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.

[2] 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 that 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, request and assignments 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:

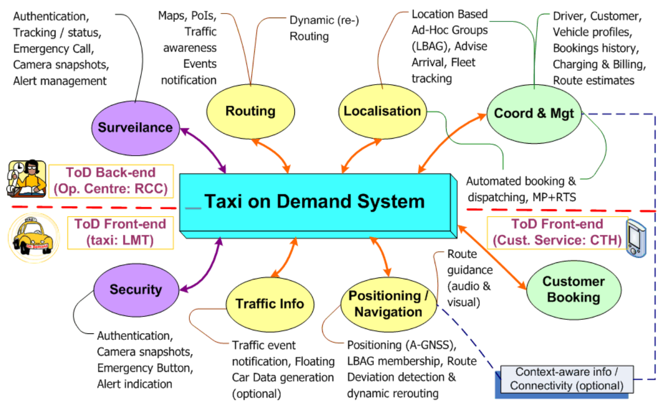

Figure 1: Taxi-on-Demand (ToD) Functional Overview

Functionalities in the above schema, are grouped as:

- Back-end functions, residing at the Operations Centre (RCC) include: Surveillance, Routing, Localization, 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.
- Front-end functions relating to services available to the customer reside in EIS (Enterprise Information System) and include booking facilities for both individual and company user, fixed or mobile.

The aforementioned functions are outlined in the sequel.

A. Surveillance / Security

The mission of these functions is to provide real-time passive protection and monitoring of the mobile worker, covering 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 an external (concealed) emergency button in the proximity of the driver. A 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 RCC/EIS and 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 driver, obtained with the help of the LMT. Localization 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. A traffic information service is implemented as a model running in real time and based on historical data collected over few weeks. It is synchronized to real situations using real time data from loop detectors installed at critical points of the road network in Athens (data provided by Hellenic Ministry for the Environment). Traffic data is imported into the GIS routing service defining a weight for each road segment indicating the decrease of travel speed with regards to the maximum travel speed allowed on the given road segment. Thus the routing algorithm is able to provide the fastest route for the current road conditions. These core functionalities are integrated in the LBS Platform (LBS_P) [6]. ToD-specific functionalities related to location based dispatching are implemented via LBAG [11], i.e. a mechanism addressing two principal issues, related to centralized systems and freelance drivers:

<u>In the centralised case</u>, the operator (dispatcher) broadcasts booking requests to all taxi drivers and waits for responses. This in effect floods the network with requests sent to 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 criteria such as proximity to pick-up point, bid time, customer preferences, dispatcher policies, etc).

<u>In the peer-to-peer case</u> LBAG publishes requests from customers only to taxis in an appropriate geographical area (ad-hoc group), which again results in optimizing network traffic. After accepting the request the taxi driver is able to communicate with the passenger, to e.g. provide booking confirmation (acceptance of request, provision of estimated cost) and notify arrival to the pick-up point.

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 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). One important feature of LBAG is that location of a servant participating in LBAG transactions is not revealed to other participants a-priori, thus enabling privacy protection and control in a multitude of centralised peer-to-peer applications. Initial analysis [11] has revealed minimal communication and cost requirements, which make its deployment feasible even over low throughput packet bearers (e.g. TETRA, GPRS).

The introduction and evaluation of LBAG leads to an extended Peer-to-Peer paradigm, for building applications that do not require a "handshaking" entity between service provider (taxi-driver) and consumer (passenger). Extension of this concept is the use of LBAG for discovering other customers of the service currently in the area, and willing to share the ride. It thus acts as a car pooling mechanism, for maximizing vehicle utilization in urban environments.

Floating Car Data (FCD) generation[3] relates to near-Real Time traffic info. Taxis, as heavily-used vehicles are best-suited for providing such info derived from their movement and whereabouts, to GIS providers, radio stations, etc.

C. Coordination & Management (COMA)

This set of functions provides real-time monitoring and operational support for the taxi drivers including:

- Dispatching Operations / Servicing booking requests and active fleet resources Management.
- Routing (mainly estimates or fixed lists[4] of route cost and time provided to the customer upon booking)
- Data acquisition (driver / vehicle-terminal / customer profile and bookings / routes history maintenance)
- Emergency calls, cabin monitoring, alert notifications.
- Driver / vehicle status (position, statistics, operability)

The management sub-system encompasses DBs with possible integration (beyond the scope of this project) with other external ERP systems, e.g. for billing / accounting, planning and optimisation tools. The Operations Centre is able to assign priority levels and status to events and allow management of customised event / resource displays. Priority assignment can be static (predefined at configuration time) or dynamic following dispatcher policies. In the current implementation, the COMA functions are accessible to the users of the Operations Centre via 2 screens (GUIs): Critical (live operations - TOG), and non-critical (BackOffice -TBG).

[3] Although potentially supported, this feature is currently out of the scope of the ToD TC pilot and demonstration.

[4] 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.

D. *Customer Booking Service*

Customer (CU) management residing in EIS, provides appropriate web-forms to the ToD customer (individual or enterprise), with functions related to booking management:

- o CU Registration forms (physical person & enterprise)
- o Authentication screens for registered customers
- o CU Profile retrieve and edit screens
- o Booking Form retrieve / edit / Submit / Get estimates
- o Retrieve / Edit / Save Points of Interest screens
- o CU Evaluation of service forms

E. *Context Aware info / connectivity*

Relates to the acquisition / automated reception of content relevant to vehicle location (e.g. local infotainment, etc)[3].

IV. TOD ARCHITECTURE

An overview of the ToD system functional architecture[5] and major operational flows is illustrated in **Figure 2**.

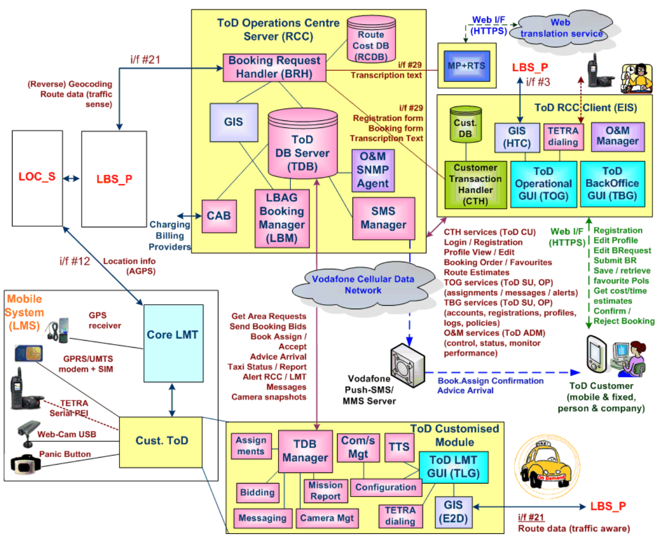

Figure 2: ToD Functional Architecture & Operational Flows

- ❑ **LIAISON Mobile System (LMS)**, is implementing the ToD system in the taxi, and comprises of the following:
  - o <u>LMT terminal</u> (Ultra-Portable PC[6]) hosting the ToD specific S/W (ToD Customised Module) comprising of TOD LMT GUI (TLG), a manager for remote RCC access (TDBM), GIS for route visualisation (using Elevated 2D method) [12] / audio guidance[7], booking request bidding manager, messaging, mission assignments, configuration, reporting, emergency TETRA dialler, communication / camera manager.
  - o <u>An emergency button</u> (self-powered USB HID Type foot switch) is attached to the LMT (concealed).
  - o <u>External passive GPS receiver</u> + antenna appropriately mounted on the vehicle (compatible with LOC_S).
  - o <u>GPRS/UMTS Data modem</u> for supporting data communications (Sierra Wireless Aircard 775/850™ plugged into to the PCMCIA port, or built-in modem).
  - o <u>TETRA terminal</u> (Sepura™ SRH3800) connecting to OTE's TETRA network for back-up voice support.
  - o <u>In-car web camera</u> (remotely connected to the LMT) for surveillance and emergency support.
- ❑ **Operations Centre Client (EIS)** comprises of:
  - o <u>TOG:</u> ToD Operational GUI client, providing for basic time-critical operations related to booking and fleet management (monitoring / management of requests and assignments, alerts, and messaging with drivers
  - o <u>TBG:</u> ToD BackOffice Operations GUI client, i.e. the screens providing for all non-time-critical operations related to ToD entities (human and non-human) profile management and history maintenance and logging.
  - o <u>CTH:</u> Customer Transaction Handler, i.e. the web pages accessed via internet by the ToD CU (both physical person and enterprise), providing all functionalities related to CU booking management (see section III.D).
- ❑ **Operations Centre server (RCC)** is the heart of the ToD system hosting basic ToD services:
  - o <u>GIS:</u> In RCC it mainly relates to the provision of route length / time estimates, as part of the BRH service triggered by submitted Booking Requests (BR) at the CTH. In EIS it relates to the visualisation of the dispatcher operational area, including BRs & taxis coloured according to their operational status, and PoIs relating to service routes.
  - o <u>TDB:</u> The ToD DB constitutes the heart of the ToD System, in terms of providing a central point of reference and data storage for all modules and services. In this context TDB provides the means for asynchronous communication between all ToD components. The main rationale for this design decision lies in the complexity and increased load of transactions and interdependencies of modules, under realistic operating conditions[8].
  - o <u>BRH:</u> Booking Request Handler handles bookings, propagating completed and confirmed requests[9] to LBM service for further processing. BRH interacts with the RCC GIS (and/or LBS_P) for the provision of estimates to the customer, based on route time / length indications and calculation of cost (interaction with the RCDB[10]).
  - o <u>LBM:</u> LBAG Booking Manager service is responsible for the publication of valid booking requests to appropriate groups of drivers, reception of driver

[5] As implementation and testing are still active, certain features may, or may not be available for pilot demo, depending on technical / budget restrictions.

[6] The DIALOGUE FlyBook™ V33i tablet PC is currently used.

[7] The LOQUENTO TTS™ text-to-speech transformer is used.

[8] A medium to large scale dispatcher today in Athens handles customer requests at the order of 18000 per day (rush hours mainly), while monitoring about 500 taxis. Customer records in its DB would be at the order of 500000.

[9] Completed requests include both current and late bookings scheduled for now, that are activated in the TDB.

[10] RCDB contains applicable tariffs and formulas for charge calculation based on Km, time of day, city zone, and extra services, as well as fixed prices and policies for certain frequent routes supported by the dispatcher.

responses, resolution of driver assignments and maintenance of the active BR records in TDB. LBM controls a number of web-pages, which correspond 1-1 to booking areas (dispatcher operational areas). BRs received are added to the web-pages based on pick-up point location. Drivers download and view the web-pages relevant to their current location, and bid for one or more booking requests. LBM collects valid bids and matches drivers to requests, based on criteria (customisable according to dispatcher policy):

- FORCE (customer request for specific driver)
- AGE (older requests precede over newer ones – drivers idle for a longer time have priority)
- SPECIAL (CU preferences such as VIP, VAN, etc)
- TIME (shortest time-path to the pickup point)
- DISTANCE (shortest Km distance to the pickup)

LBM communicates asynchronously with the rest of modules via the TDB and can thus be easily deactivated to turn the system into "Manual mode" where the human dispatcher (operator) manages assignments.

- o SMSM: Provides Book Assignment confirmations (SMS message providing taxi ID and pick-up data) and Advice Arrival notifications (SMS message alerting for taxi arrival) to the customer using ToD services.
- o O&M: Operation & Maintenance in both EIS and RCC hosts management functions relating to the operation of the ToD application and all supporting S/W and H/W.
- o CAB: The Charging Accounting and Billing component collects charging records related to network transport and ToD system use, and bills from content / service providers. Taxi drivers are invoiced (one-stop-billing) for their use of the communication network, GIS content (maps) and location services (LBS_P / LOC_S use).

- ❑ **Multilingual / Transcription support (MP+RTS)** component provides assistance to the CU for carrying out the filling of the booking request form and other tasks provided by the EIS (CTH) web-service. This is done by providing multilingual support (menu selection, street names and PoIs) and free-text transcription[11] (customer text). Multilingual menus are also available to the Operator (TOG / TBG) and the driver (TLG).
- ❑ **Voice calls for emergency / backup (TETRA)** in ToD is accomplished over OTE's TETRA infrastructure through the use of terminals connected to the LMT and RCC/EIS via the serial PEI interface. Voice bearers are terminated at the TETRA terminal, and an automated procedure is defined for dialling PSAP numbers (e.g. in emergency, or data communication failure situations).
- ❑ **Data communications (normal operation)** The ToD LMT uses a Sierra Wireless cellular HSPDA / UMTS / EDGE / GPRS modem. The main issue regarding this communication is the inability of the RCC to access the LMT, due to addressing restrictions (NAT and firewall of mobile operator). Thus the LMT has to access RCC periodically, to both send and receive operational data.
- ❑ **LBS Platform (LBS_P)** containing ToD demo (Attica) area Maps and the relevant no-turn, direction, and PoI information, is implemented as a physically separate server, providing traffic aware routing, navigation / route guidance, and (reverse) geo-coding data (traffic-aware route estimates used by BRH).
- ❑ **Location Server (LOC_S)** hosting A-GNSS positioning information (A-GPS) for ToD.

V. Conclusions And Extensions

The 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 taxi fleet operators.
- ➢ Route guidance addresses credibility issues providing for increased transparency for 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, ToD also delivers 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 in the taxi provides an additional revenue potential for taxi sector. Internet connectivity, mobile office facilities, multi-lingual support, 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.

In addition to the above, a new business paradigm is enabled by technologies such as LBAG, providing peer-to-peer services, 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

[11] MPRTS in TOD is currently based on a web-translation service (by WorldLingo™) accessed via a SOAP I/F and capable of processing textual input of up to 150 words within a maximum of 3 seconds.

required by major dispatchers today, 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 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.

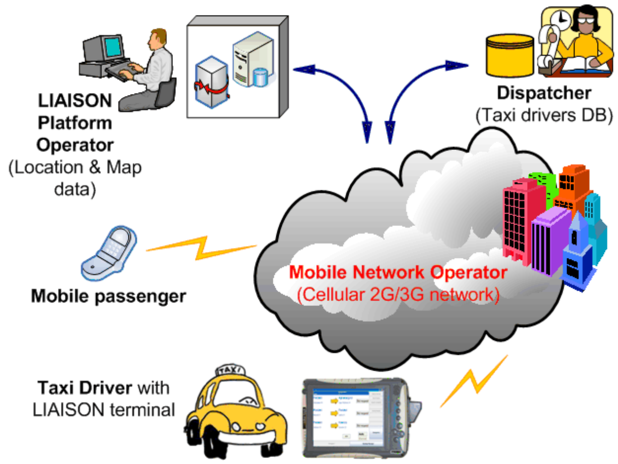

Figure 3: Peer-to-peer Taxi hailing actors

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 and monitoring systems. The 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.

Acknowledgment & Disclaimer

This paper has been written in the frame of the research activities of the European project IST IP LIAISON-511766. LIAISON has received research funding from the EC's 6th Framework Programme (FP6). The authors would like to thank their colleagues in WPs 2, 3, 4, and 5 for their contribution in specifying / designing / implementing core LIAISON parts integrated in ToD. The EC has no responsibility for the content of this paper. Information in this document reflects only the views of the authors, and is provided as is, and no guarantee or warranty is given that the information is fit for any particular purpose.

References

[1] EGNOS web-site: http://www.esa.int/esaNA/egnos.html. Europa: http://europa.eu.int/comm/dgs/energy_transport/galileo/intro/steps_en.htm

[2] GALILEO web-site: http://www.galileoju.com/. Europa: http://europa.eu.int/comm/dgs/energy_transport/galileo/

[3] LIAISON *Service Definition Pre-op Deliverable 055*: document *3300_D055-Service-Definition_LIA-REQ-DEM-02_3C*, Jan 2006.

[4] European Commission Recommendation, *Official Journal L 189,* 29/07/2003 pp. 0049 – 0051.

[5] LIAISON *Market Analysis Deliverable 036:* document *2701_D036-Market-Analysis_LIA-RP-HITEC-02_3D,* Aug. 2005

[6] LIAISON *System Solution DDF Deliverable 041:* document *0306_D041-Liaison-System-Solution_LIA-RP-ASP-03_2D*, Jan. 2006

[7] Athens congestion map: http://www.transport.ntua.gr/map/en/index.php

[8] LIAISON *ToD Customized Module Design Del 041*: document 3312_D041-ToD-Cust-Module-Design_LIA-DF-DEM-03_1B, Jan. 2006

[9] http://business.singtel.com/upload_hub/mnc/SmartCab_Mar_2004.pdf

[10] http://www.netsize.com/pdf/en/TaxiPoint_NetsizeBC.pdf

[11] S.C.A. Thomopoulos, N. Argyreas, E. Makri, P. I. Philippopoulos and D.K. Bougoulias, "*LBAG: A Location Based Ad-Hoc Grouping Mechanism for Location Aware Booking Services*", Proceedings of the 15th IST Mobile Summit 2006, Mykonos, Greece, 7 June 2006.

[12] Artur Krukowski and Stelios C. A. Thomopoulos, "*Improvement of GPS Positioning Availability using Ground Elevation Information*", 15th IST Mobile and Wireless Summit 2006, Mykonos, Greece, 4-6th June 2006.

[13] Stelios C.A. Thomopoulos, Panos I. Philippopoulos, Nikos Argyreas, Artur Krukowski, Effie Makri, George Soulos, and Christos Dessiniotis, "*LIAISON IP Location Based Services: Taxi on Demand*", Proceedings of the 15th IST Mobile Summit 2006, Mykonos, Greece, 7 June 2006.