LBAG: A Location Based Ad-hoc Grouping Mechanism for Location Aware Booking Services

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Abstract— **In this paper we present and analyze in terms of application architecture and communication requirements a novel mechanism for Location Based Ad hoc Grouping (LBAG), suitable for providing location aware booking services by matching service supply with demand without revealing user data (position) prior to the completion of the booking transaction. LBAG has formed the cornerstone of the implementation of a Taxi on Demand (ToD) application in the context of the FP6 IST LIAISON Integrated Project. LBAG operation requires no human intervention, unless deemed necessary in emergency cases, and has minimum bandwidth requirements.**

Index Terms **— FP6 IST LIAISON, Location Based Services, Location Based Ad-hoc Groups, Taxi Dispatching, Car pooling.**

I. Introduction

A significant amount of work has been done in the area of distributed systems, addressing concepts particular to ad-hoc groups' organization & realization, ranging from membership determination to dynamic allocation of identities and their management [1, 2]. Application domains include fleet and spread teams' management, where dynamic creation of ad-hoc groups based on location and other matching parameters can simplify the manager's tasks.

An ad hoc peer-to-peer group can be defined as a self organising group comprised of entities which cooperate in order to dynamically establish communication. All entities are equal and all contribute some of their resources, therefore each entity can be considered as both a service consumer (client) and a service provider (server). The term "servant" is used in literature to denote this [2]. Location-based ad-hoc grouping (LBAG), in the context of the IST LIAISON project [1, 3] is a centralised ad-hoc peer-to-peer mechanism for matching supply with demand for location dependent services, i.e. whereby group membership determination is primarily based on the peer entity's given position.

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The 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. This approach is particularly useful in real life paradigms such as taxi / car-pooling, where privacy protection is essential. Taxi drivers and car-pool providers (vehicles) may form a location-based ad-hoc group in order to accept requests from customers / car-pool members in the vicinity, without relying on human-operated dispatch systems for managing the service.

II. LBAG Use Scenarios Requirements

In the sequel a brief outline is provided regarding the requirements of two use scenarios for application of the LBAG mechanism in the context of LIAISON, namely the Taxi on Demand (ToD) and the Fire Brigade Intervention (FB).

A. ToD high-level requirements

In Athens, Greece, a city of more than 4 million people, there are approximately 15000 taxis (corresponding to 25000 drivers) who may take passengers off the street, or via a call through a taxi dispatch company. About two thirds of taxi drivers are freelance (called "road warriors"), while one third are members of some company which incorporates a radio dispatch centre.

"Road warriors" do not belong to any specific company, but operate with a limited clientele (pre-arranged customer bookings), employing limited technological capabilities (usually their mobile phones) to communicate with other drivers and customers. Taxi companies on the other hand, defined mostly as "cooperatives", employ human operators in a dispatch centre for providing route assignments. Requests are broadcasted on a common radio channel once a call for service is made to the centre, and drivers in the vicinity, who believe they can accommodate the request, respond and one of them is assigned by the human operator. Taxi companies are improving and there is a recent interest by users to move from the CB network to TETRA.

There are different characteristics and priorities [4] regarding taxi drivers requirements at work, in temporal and/or spatial context. At night, security comes first as a priority, while long rides to busy areas are preferred. In general, at night it is often difficult to get a customer on return routes, so drivers want to avoid rides away from the centre. Also drivers try to take advantage of the rate duplication after midnight. During the day in the downtown area, roads are jammed and taxis are in strong demand. So drivers, and in particular road warriors, put a premium on high occupancy and try to fit as many people as possible in the taxi, often denying rides to parties of two or more people, or people with luggage. Other limitations in the taxi business include:

- The majority of taxis are not equipped with any type of electronic navigation system. Drivers rely on conventional maps for routing, radio & other drivers for directions.
- No localisation functionality is currently available. Dispatch centres rely on driver input via voice communication.
- No data communications except for codes identifying zones being sent to the dispatch centre via the CB radio.
- There is no direct contact between drivers and customers. Customers communicate only with the dispatch centre.
- There is no real-time traffic information provided to the drivers, who have to rely on various radio stations which give general traffic reports during the day.
- There are no security mechanisms in place to help the driver in case of an emergency.

B. FB high-level requirements

Firemen face unknown and sometimes complex environments, especially when dealing with fires e.g. inside a building, an underground parking, or at an industrial site. Tough conditions often impair the firemen's deployment capability and induce situations endangering their lives [4].

Fire brigade intervention is initiated with an emergency call which is answered by a PSAP (Public Safety Access Point) operator. The operator then dispatches the appropriate resources. When the firemen arrive at the intervention site, each fireman is allocated a task, whereby the overall task is to extinguish the fire and rescue any people in distress.

The following issues arise:

- Communication with colleagues inside the building is not possible, due the breathing apparatuses worn / smoke.
- Communication with colleagues outside the building is not possible.
- If several squads are involved with the intervention, coordination on site is difficult.
- In the case that a fireman is in distress, this is not detectable by colleagues.
- Orientation inside a building that is filled with smoke is not possible.
- Firemen are physically injured by heavy falling objects.
- Firemen are completely encircled by fires.
- The fire engine might be involved in an accident.
- Navigation to the intervention site might be difficult with out of date maps.

The fire brigade has to go to the intervention site as fast as possible by using the most optimum route in terms of time, therefore navigation is crucial.

III. Taxi on Demand Scenario

In this paper we focus on the "Taxi on Demand" scenario, where the users of the LIAISON system are taxi drivers and dispatch centre operators. Booking requests from potential passengers come into the dispatch centre via a web service, are processed and sent to the LIAISON Mobile Terminals (LMTs) fitted in the taxi vehicles, for display to the taxi drivers.

A. Implementation Architecture

1) Pre-defined Grouping of Geographical Regions

A geographical region of interest is divided into virtual grids of hexagonal shape, each denoting a group[1], as illustrated in Fig.1. Grids are appropriately planned considering booking request statistics, and taxi companies' operational policies.

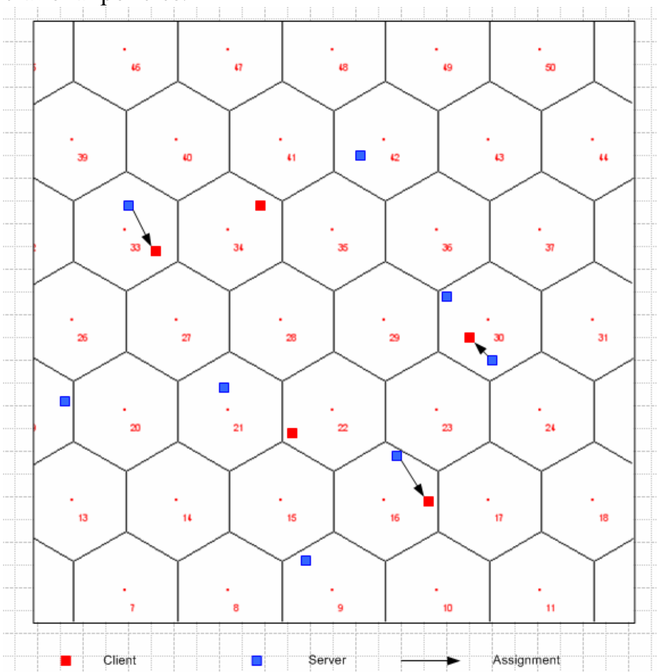

Figure 1. LBAG area segmentation

2) The LBAG Client/Server Model

A potential passenger possessing a java-enabled mobile phone/device may download the ToD application (MIDlet) onto his/her handset [5], and issue a booking request for a taxi by filling in a data form in the language of his/her choice. An http session is established between the potential passenger and the ToD web service residing on the Enterprise Application Integration (EIS) system (see Fig.2). The request is sent to the Remote Control Centre (RCC)[2], where the Booking Request Handler (BRH) handles all the interactions with the customer. Once verified, the request is sent to the LBAG Booking Manager (LBM) which publishes it to the appropriate group of drivers, receives their responses and decides the winner in cooperation with the ToD Dispatcher Application (TDA).

Booking requests are appropriately classified and grouped

[1] In the unlikely case where a client or server belongs to more than one groups (hexagon border) the system randomly selects one of the groups, or utilises direction information if available to decide membership.

[2] The LIAISON RCC is essentially the Dispatch Centre in ToD. Here all the appropriate processing and management for the booking is performed.

in lists according to the geographical regions of the service. Thus LBM controls a number of web pages which correspond to pre-defined group areas within the service coverage (Fig.3).

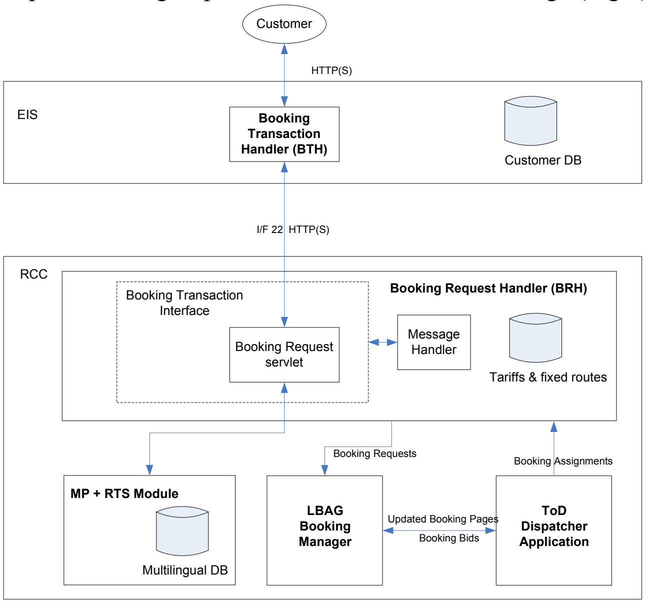

Figure 2. Overview of "Dispatcher" Side Booking Management

Each booking request received is added to the web-pages whose corresponding areas contain the pick-up point location of the request. Drivers may only download and view the web pages which are relevant to their current location.

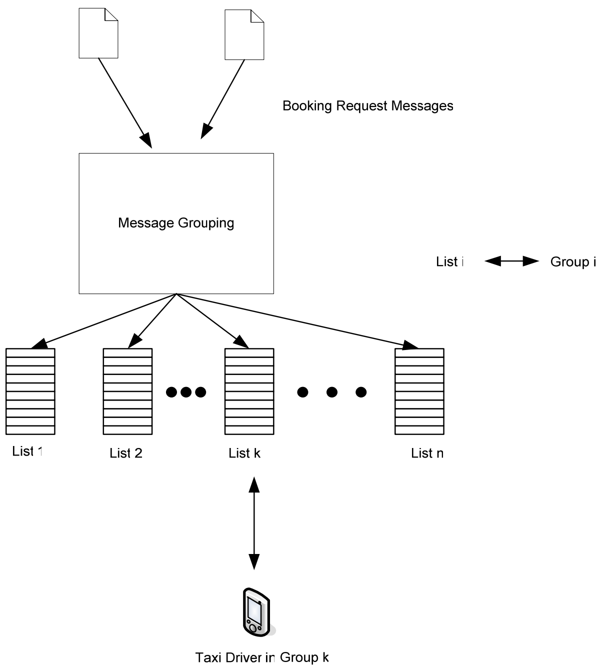

Figure 3. LBAG Booking Manager

Web pages contain the entire booking requests list for that area, however only a subset of these may be viewed by the drivers, filtered by the LBAG client application in the LMT, on the basis of passenger default or custom preferences (e.g. driver language), or taxi flag status. Taxi drivers may bid for one or more booking requests, and post the form back to LBM. The LBM then collects valid[3] responses, runs a criteria-driver selection algorithm[4] and proposes a solution to the TDA module for further processing in the form of booking records[5].

An example LBAG client bid-form is depicted in Fig.4.

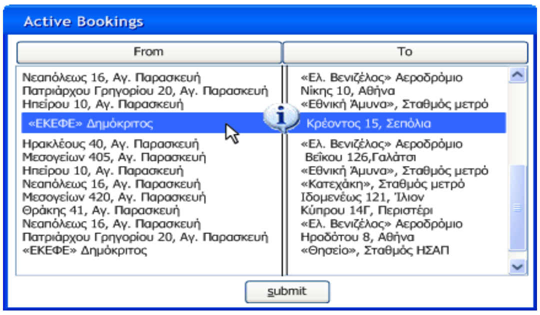

Figure 4. LBAG client Bid Form (example)

If a booking request is not serviced after a pre-defined period of time, the LBM may re-publish it to a wider set of pages, i.e. corresponding to neighbouring groups, or delete / deactivate it temporarily, or permanently. If an appropriate match to the request is found, the winner is provided with a booking assignment indication, as illustrated in Fig.5.

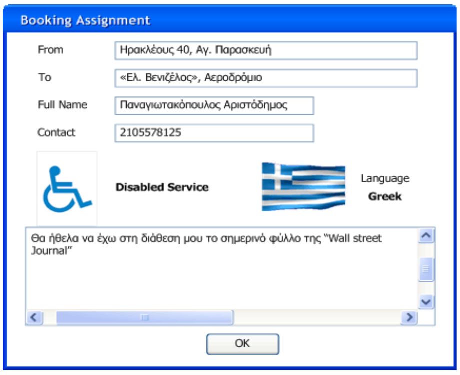

Figure 5. LBAG client Booking Assignment (example)

The booking assignment is confirmed by the driver, providing also an updated time of arrival to the pickup point. The customer is then informed via SMS/MMS of the vehicle and driver ID, including also refreshed cost and time estimates. An additional "Advice Arrival" notification is sent upon arrival of the taxi to the pick-up point.

On the client side, the HLBAG module is responsible for refreshing the LMT's membership to the pre-defined groups, based on LMT location. The basic component of this module is a control thread which obtains the absolute location data

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[3] Submission of responses may be disabled if the taxi is currently occupied, depending on local regulation. Alternatively, permission to submit bids may depend on expected time of arrival to destination point for the route currently serviced. Once having submitted a response to a certain request, the driver cannot re-submit for the same request.

[4] Criteria used relate to time (older requests take precedence), distance (nearest taxi), as well as special client requests (VIP, disabled, etc).

[5] Each booking record has the following information associated with it: *booking ID, cost estimation, time to arrival estimation, time to destination estimation, pick-up location, destination location and a time stamp*.

from the embedded GPS hardware module (including A-GPS corrections from a corresponding LIAISON service - HAGS).

Most of the time the thread is idle (sleeping/suspend mode). LBAG group data resides into the LBAG group specification file (Fig.6). The LBAG file I/O component reads the group data from the specification file and triggers the thread.

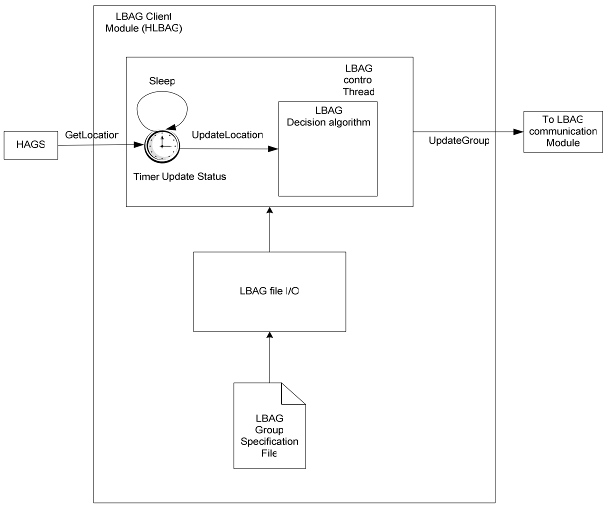

Figure 6. LBAG Client Module (HLBAG)

The LBAG communication module (Fig.7) consists of the LBAG communication thread which downloads the booking pages according to the current group the LMT belongs to, periodically (incremental), or by triggering of the HLBAG.

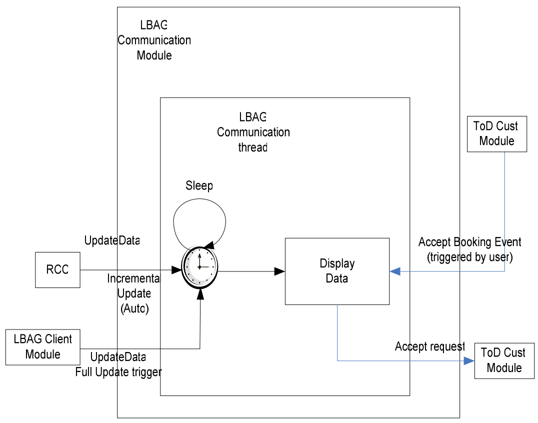

Figure 7. LBAG Communication Module

IV. ANALYSIS OF LBAG COMMUNICATION REQUIREMENTS

Performance analysis in the sequel assumes that grouping is based on a hexagonal grid scheme (fixed radius) providing full coverage of the service area. In the most simplified case each hexagonal corresponds to one group. In real life, a group may correspond to more than one hexagonal, especially for non-densely populated areas. The grouping policy also corresponds to the size of the dispatcher/taxi company.

A. Generic parameters

Parameters relating to the load of the booking system:

- Number of groups: *g* (fixed number)
- Connected users: *u* (i.e. available taxi drivers)
- Calls per minute: *r* (i.e. booking requests)

B. Timeouts and group indices

Timeouts occur when a booking is not served for a period of time. Three timeout periods (see grouping boundaries in Fig.8) have been defined for the booking process, as follows:

- 1st timeout period: system searches for an available user (taxi) in the specific group where the customer is located.
- 2nd timeout period: if no booking bids are received during the first timeout, the system searches for an available user in the six neighbouring groups.
- 3rd timeout period: if there are still no responses during the second timeout, the system searches for an available user in the twelve neighbouring groups.

If there are still no responses, or the request has been served, the corresponding index is deleted from all group lists.

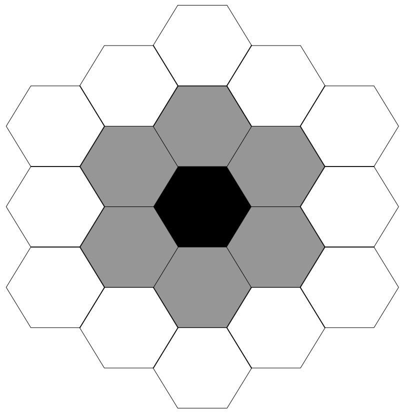

Figure 8. Search areas during system timeouts

Each request is identified by a unique index. Therefore, the maximum number of indices for all groups (html pages) during the three timeouts is calculated as follows:

$$L = (t_1 \cdot r) + 7(t_2 \cdot r) + 19(t_3 \cdot r)$$

The average number of indices per page is:

$$l(avg) = L / g$$

The refresh rate of the page downloaded, defined as *List update timeout* corresponds to *Δt.*

C. Estimation of Performance

Each index comprises of the fields shown in Table 1.

Field	Type	Size
Location data	float, float	2×32 bits = 64 bits
Timestamp	Time/Date	64 bits
Hits	integer	32 bits
Preferences	bit array	16 bits

Table 1: Index Fields

From the above, the total size per index is:

$$spi = 64 + 64 + 32 + 16 = 176 bits$$

Thus, the average size in bits per page is calculated as follows:

$$LS(avg) = l(avg) \cdot spi + OVR = 176 \cdot l(avg) + OVR$$

OVR is the communication overhead, i.e. a constant measure relating to the communication protocols (HTTP, TCP/IP). As the LBAG mechanism is network agnostic we can decouple it from the underlying carrier performance, and further assume that this measure is negligible as compared to l(avg)[6].

If all timeouts are equal in duration, i.e. $t_1 = t_2 = t_3 = t = 2$ *min*, then $L = 54r$.

Let U be the updates per minute. If U = 2 (i.e. $\Delta t = 0.5$ *min),* then the total network bandwidth in bps (for all the connected users) per second is:

$$B = u \cdot LS(avg) \cdot U / 60 = 2u \cdot LS(avg) = u \cdot 352 \cdot l(avg) / 60$$

The total network bandwidth in bps (per user) per second is:

$$b = \frac{352L}{60g} = \frac{352 \cdot 54r}{60g} = 316.8\frac{r}{g}$$

Table 2 illustrates the above calculations in ToD:

g	50	60	70	80	90	100
r	***b (bps)***					
10	63,36	52,80	45,26	39,60	35,20	31,68
20	126,72	105,60	90,51	79,20	70,40	63,36
30	190,08	158,40	135,77	118,80	105,60	95,04
40	253,44	211,20	181,03	158,40	140,80	126,72
50	316,80	264,00	226,29	198,00	176,00	158,40
60	380,16	316,80	271,54	237,60	211,20	190,08
70	443,52	369,60	316,80	277,20	246,40	221,76
80	506,88	422,40	362,06	316,80	281,60	253,44
90	570,24	475,20	407,31	356,40	316,80	285,12
100	633,60	528,00	452,57	396,00	352,00	316,80

Table 2. Test Results (bits per second)

Based on a worst case scenario where every request remains in the list during all three timeout periods and all the users are receiving new requests (despite the fact that a user already serving a request should not receive new requests), we estimate in the table below the maximum number of LBAG customer (passenger) requests that three different wireless networks, each with a different bandwidth availability, namely TETRA, GPRS and 3G, can support. It can be seen that even in the case of TETRA, which offers the lowest bandwidth, the number of requests that can be handled per minute exceeds one thousand, even in the most unfavourable case with the fewest number of groups (50).

g		50	60	70	80	90	100
network	***b***	***r (requests per minute)***					
TETRA	7.344	1.159	1.390	1.622	1.854	2.086	2.318
GPRS	46.080	7.272	8.727	10.181	11.636	13.091	14.545
3G	393.216	62.060	74.472	86.884	99.296	111.709	124.121

Table 3. Number of requests services per minute

D. Cost considerations

To provide an indication of cost, the cost per call to the taxi driver has been approximated based on the current advertised rates of GPRS in Greece (Vodafone GR). Assuming a data connection with cost 0.0019€/KByte, and given that the estimated total size per index (request) = 176 bits, we obtain a cost indication per request = $4*10^{-5}$ €. Even though this approximation does not take into account the actual charging per packet used by the mobile operator, it is still indicative of the low cost of the LBAG solution requirements.

V. CONCLUSION

In this paper we presented a centralised peer-to-peer location based ad hoc group (LBAG) mechanism that allows effective service provision to a localized user (or groups of users), via updating of a set of groups without the need for each member of a group to reveal his/her position. The LBAG mechanism allows service consumers and service providers to interact in an efficient and automated manner without the need of human intervention, in non-emergency situations. A theoretical analysis of the proposed method reveals minimal communication and cost requirements. The method has been applied in the Taxi on Demand (ToD) test case in the LIAISON [3] project. The method is applicable in a range of centralised peer-to-peer location-based service paradigms, where privacy plays a critical role.

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[6] When a group page consists of 1000 indices then l(avg) · spi ≈ 176Kbytes.