Towards Enhanced Location-based Services through Real-time Analysis and Mobility Patterns Acquisition

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***Abstract*-This paper presents a work in progress towards a middleware platform to support enhanced location-based services through real-time mobility analysis and mobility patterns acquisition. The platform provides services for mobile users and also for mobility analysts. Mobile users are enabled to receive notifications in response to emergency, contingency situations or deviations from mobility patterns. Mobility analysts are enabled to analyse mobility behaviour of users during time scales and territorial scopes as well as to obtain and program mobility patterns and indicators of mobile users and groups of users. Enhanced location-based services are possibly if and only if powerful and efficient capturing, pre- and post-processing of mobile information schemes are adequately implemented and put in place in favour of ubiquitous location service provisioning.**

Keywords-Location-based services; mobile information processing; global position.

I. Introduction

The study and analysis of mobility and transport aspects have taken on increased importance in recent years, in particular the ones that affect urban sustainability and urban policy [1] [2]. In general terms, current diagnosis of the mobility and transport systems' sustainability base their studies mostly on static models such as the usage of general indicators such as average distances travelled, changes in shifts and changes in the location of productive activities.

To date, there is a lack of mobility systems that deliver real-time services aimed at warning mobile users during a trip with alternative routes in response to emergencies, contingency, and/or congested roads, all in all, considering accurate measurements of mobility patterns. A system like this would be complex, highly dynamic and should be able to deal with a large number of participants, making its applicability difficult for specific contexts such as emergencies, traffic congestion, weather contingency, maintenance of traffic infrastructure, etc., as they should be able to react automatically and they should scale.

In order to assess systems of this kind, there is a need for further analysis of dynamic operational aspects such as the nature of the information available, the type of indicators to use or references to territorial units for ad-hoc applications to particular circumstances [3]. Location Based Services are a set of tools that provide personalized services with help from the user's geographic location or other moving object of interest [3]. These services provide accurate location information through mobile devices such as cell phones, Global Positioning System (GPS) [3] or Radio-frequency identification (RFID) [4]. A location-based service is not necessarily limited to locating and tracking the mobility of a mobile entity. Moreover, these services could be extended towards orientation or navigation services by exploiting the user's location to allow build roads on a map, indicate routes step by step under specific circumstances, determine the distance to travel and display sites that may be of interest to the mobile users [5].

This paper presents our work in progress towards a location-based service platform that provides support for advanced mobility services through real-time analysis of mobility information and generation and usage of mobility patterns. The service platform is envisioned as a platform sensible to dynamic operational aspects such as the nature of available information about routes and mobility, the type of indicator to use, referenced territorial units for ad-hoc applications, and real time and large scale analysis. The targeted system is a location-based service platform whose core functionality is the analysis of mobility information. In particular the platform provides support to help acquiring patterns of mobility that can be used to generate alerts when patterns are not met during a trip of a mobile user. Although the service platform can be thought of being ideal for transport systems, it is possible to use it with services such as security through freight monitoring, assistance for drivers in case of eventual circumstances (e.g., emergency, weather contingencies, etc.), in which notifications are sent automatically to mobile users through the platform.

After this Introduction, Section II presents the conceptual framework of the target platform. Section III presents the preliminary implementation steps, and finally, Section IV concludes the paper.

II. Conceptual Framework

This section describes the framework and challenges of the proposed services platform shown in Figure 1.

A. Conceptual Framework

The platform provides services to mobile users and to mobility analysts, which are described hereafter.

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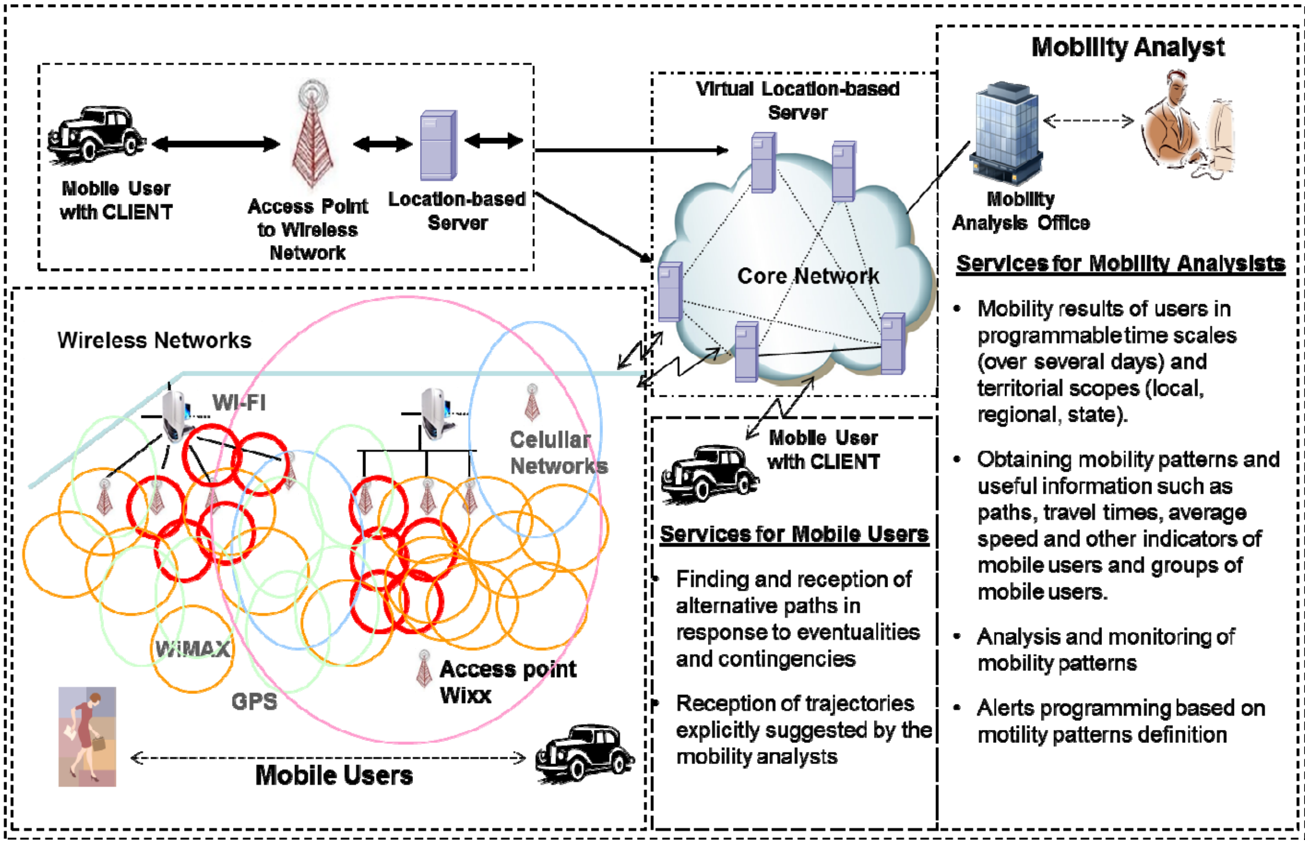

Figure 1. Services supported by the location-based service platform

Figure 2. Example of location service for mobile users

From the mobile user viewpoint, the platform provides support in finding alternative paths in response to eventualities and contingencies, and it also provides support to follow trajectories explicitly suggested by a mobility analyst, who will also be user of the platform. Figure 2 shows an example of the location services for the mobile user, where two alerts are sent to the mobile user as a result of a contingency event, accident, etc. These alerts are sent by the platform as a result of real-time mobility information analysis of other users of the platform.

For the mobility analyst the platform provides support in aspects that include; obtaining results of location and trajectories of various mobile devices during the day and during periods; obtaining mobility results of programmable time scales (over several days) and territorial scopes (local, regional, state); obtaining mobility patterns and useful information such as paths, travel times, average speed and other indicators of mobile users and groups of mobile users. Figure 3 shows examples of services for the mobility analyst. On the left, the trajectory followed by the user in two consecutive days is displayed, where the time traveled, average speed per path segment, and historical information are also available to the analyst (not shown). The center of Fig. 3 shows the area where the user spent more time, time of entry and exit in the two analyzed days. Finally, the right part of Fig. 3 shows the regions of interest, number of visits made by the user, number of mobile users in the region, etc.

The mobile user can navigate to any place and the location data are collected by the platform based on a client-server design. The platform records the GPS locations of the users' mobile devices. The process of monitoring and subsequent automatic data processing takes place invisibly for both, the mobile users and for the mobility analyst.

B. *Technological Challenges*

For the realization and implementation of the location-based platform described above, it is being necessary to conduct major study on three fundamental aspects, which are briefly described hereafter.

Capturing and pre-processing of mobile information. This aspect deals with the critical nature of monitoring a large number of mobile entities as well as assessing the inter-operation between networks and the need for high bandwidth at critical periods [6]. It also faces the problem of developing algorithms for the generation of location points and the estimation of reliable paths from inaccurate GPS data and missing information due to the unavailability of the GPS signal. Particular problems are the imprecision and uncertainty in GPS data, and the different connotations and semantics of the different types of information from the mobile entities [7].

Information clustering and processing. This aspect faces the problematic of developing algorithms for discovering and predicting mobility patterns under a two-level stream clustering approach: 1) clustering based on time and location; 2) space-based clustering to obtain regions of interest. The central problems of this aspect are: massive information; integration of heterogeneous information from geographical, temporal and population information viewpoints [8] [9]; high computing time and memory requirements required to perform the clustering and processing of location information collected. The latter problem is a motivation to use advanced techniques for optimizing computer resources. Finally, another issue that deserves special attention is the lack of homogeneity in the length of the location data to analyze.

Middleware for the location-based services platform. The purpose of the middleware is to facilitate the development and operation of location-based mobile applications in an environment of technological heterogeneity [10].

The middleware provides filtered information and generates notifications under pre-programmed mobility patterns and/or mobility behavior. The core challenges for the realization of a middleware of this kind are: high data change rates and information updates; need for analysis and interpretation of information at different levels; adaptability and asynchronous interaction; and the aggregation, updates and cancelation of service subscriptions and notifications to mobile users [11].

III. Preliminary Implementation

This section briefly presents the preliminary implementation of the location-based platform described above. In particular, we shortly describe the key aspects of the client-side software architecture that is being currently developed to obtain user's location by using GPS-enabled smartphone devices. Our technological choice is based on the fact that such ubiquitous devices are becoming essential contributors to location-based services as they can provide position information accurately. Smartphones are enabled with a communication channel to send and receive information and therefore, personalized or location-dependent information can be delivered through this channel in order to enhance interaction and deliver high level knowledge. Location data depicting mobility patterns or human behavior can be obtained at large-scale both longitudinally and population-wise.

A. *Client-side implementation*

The preliminary mobile entities implement a client-based architecture to enhance location-based services in smartphone devices. The main goal is to develop a middleware to improve the smartphone software architecture for continuous and efficient services for location data by: a) providing location information at suitable abstraction level, b) collecting and storing meaningful location data, and c) optimizing energy consumption for continuous sensing. Figure 4 shows a simplified block diagram of a device-side model whose main components are briefly described hereafter.

Figure 3. Examples of location service for the mobility analyst

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The *Duty cycle adapter* provides the mobile sensing application with the position information. It abstracts the positioning methods and devices (GPS) that can be used to obtain locations and it is in charge of their parameter configuration (adaptive sampling and duty cycling).

The *Orchestration policy module* maximizes the accuracy of monitoring mobility and optimizes location updates according to a sensing policy on diverse smartphone usage scenarios (pedestrian or driving modes) with a given energy budget.

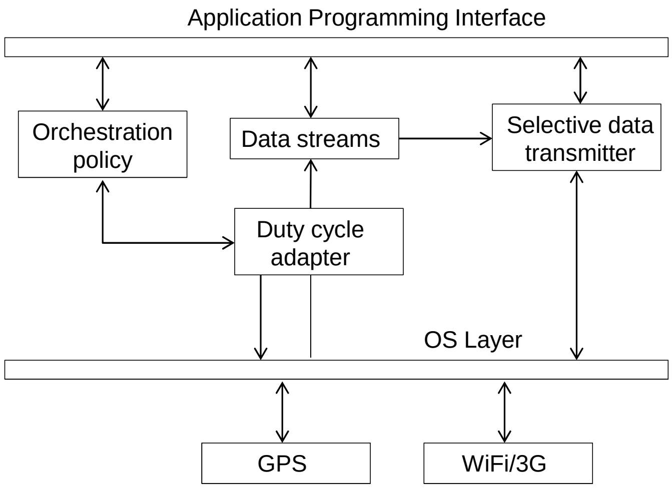

Figure 4. Block diagram of the client software architecture

The *Selective data transmitter* manages local data streams storage and the communication with the server. It provides standard ways to transfer data from/to the clients to/from the server (HTTP [12], HTTPS [12], TCP [12], and UDP [12]) selected according to the applications requirements (e.g., continuous real-time data).

Currently a prototype has been developed built on the software stack on Android-powered smartphones to evaluate the functionality and performance of the client-side architecture.

B. Server-side implementation

Data collected with a mobile device are enough to reveal an interesting pattern on their own. However, when processed through models, and algorithms on series of external and cross-user data sources, simple data can be used to infer complex phenomena about individuals and groups. To make mobility data and location-based services more readily accessible to smartphones, higher level data abstractions are needed at the cost of storage and computation. A preliminary version of a server side architecture is being explored according to the general layered organization shown in Figure 5.

The *communication layer* manages connectivity with the mobile sensing devices. The functionality of this component must match that included in the client-side software architecture. The *data collection and storage* component stores location data in databases. The visualization module shows the information to the mobility analyst. The *data analysis* component analyzes user trajectories at different scales spatially and temporally to automatically extract mobility patterns. This component uses historical data stored in the database to perform inference, correlation, and data analysis tasks to provide a complete view of situations.

The current efforts have been oriented to explore low-level preprocessing techniques for location streams since multiple measurements in the same location do not necessarily yield to the exact same coordinates due to errors and variations in the measurements. For instance, two estimated stay points could have the same semantic meaning, but not necessarily the same exact coordinates. Additionally, geometric and fingerprint based algorithms are being evaluated for the automatic learning of regions of interest since it is a key task to study mobility patterns and human behavior. Such algorithms might be used as the basis for predicting user movements or decision making based on location.

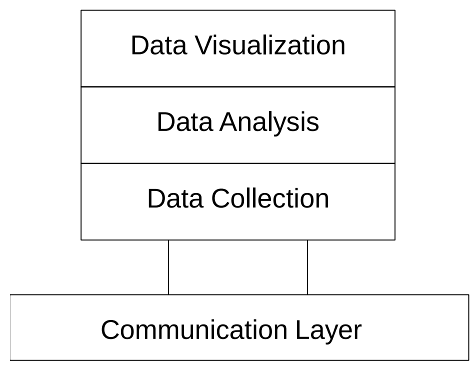

Figure 5. Block diagram of the server-side architecture

IV. State of the Art

Zheng et al. [8] proposed a method to detect inconsistencies in city planning through long-term analysis of GPS trajectories of taxicabs in urban areas. The method relies on identification and correlation of pairs of regions with salient traffic problems. Even when this method analyses large scale data during long runs, it is somehow preprogrammed to a single pattern of correlation, which is the correlation of pairs of regions with salient traffic problems. The method does not support programmability of mobility patterns (it has only one), and does not deploy location-based services to mobile users at all.

White et al. [9] propose an in-vehicle automatic accident detection and notification system to eliminate the delay between accidence occurrence and first responder dispatch. The system is based on iPhone and Google Android platforms, which can automatically detect traffic accidents using accelerometers and acoustic data, and also the provision of GPS coordinates in case of accident occurrence. This method uses context data to avoid false positives but it does not include characteristics proposed in our platform. To mention some, the

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proposed method does not correlate mobile data with other mobile entities or it does not warn mobile users when risky areas for example rainy areas are present in one vehicle's route.

Tzung-Shi et al. [2] propose a method to analyze user movement behavior patterns though standard graph-matching algorithms, which are run over mobile information stored in database systems. Even when the method has been proven to be effective in terms of execution efficiency and scalability, the proposed procedures do not include mobile service deployment of services and the programmability of patterns characteristic proposed in this paper.

Zheng et al. [13] report on a personalized friend and location recommender system for the geographical information systems (GIS) on the Web. Individual interests in (un)visited regions are estimated by involving user's location history and those of other users. The method is based on hierarchical-graph-based similarity measurements to uniformly model individual's location history, and to effectively measure the similarity among users. The proposed system is proven to be effective to find similarity-related metrics like [14] similarity-by-count, cosine similarity, and Pearson similarity measures. However, the method does not provide support to define programmable patterns and exploit them in favor of enhanced ubiquitous services.

All the related work in the literature are mostly intended to analyze acquired mobility information either to deduce mobility patterns, interests, behaviors and so forth. However, the vast majority of works do not allow mobility pattern analysis programmability. To the best of our knowledge, to date there is a lack of systems that exploit mobility pattern information in favor of ubiquitous services provision with energy saving guidelines, and where location-based services can be deployed over mobile clients as response to programmable alerts triggering.

V. CONCLUDING REMARKS

This paper has presented work in progress towards a middleware platform to support enhanced location-based services through real-time mobility analysis and mobility patterns acquisition. The technical challenges for its realization, namely, capturing and pre-processing of mobile information, information clustering and processing and the implementation of a middleware for platform, have been partially addressed. The preliminary implementations of the conceptual framework presented in this paper indicate that the proposal is feasible, and also, have provided some guidelines for its finalization.

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REFERENCES

[1] Ganti, R.K., Fan Ye, and Hui Lei; , "Mobile crowdsensing: current state and future challenges," Communications Magazine, IEEE , vol. 49, no. 11, pp. 32-39, November 2011. doi: 10.1109/MCOM.2011.6069707.

[2] Tzung-Shi Chen, Yen-Ssu Chou, and Tzung-Cheng Chen; , "Mining User Movement Behavior Patterns in a Mobile Service Environment," Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions on , vol. 42, no. 1, pp. 87-101, Jan. 2012, doi: 10.1109/TSMCA.2011.2159583.

[3] Chon, J., and Hojung Cha; , "LifeMap: A Smartphone-Based Context Provider for Location-Based Services," Pervasive Computing, IEEE , vol. 10, no.2, pp. 58-67, Feb. 2011. doi: 10.1109/MPRV.2011.13.

[4] Henrik Ljøgodt Moen, Thomas Jelle, and Tradløse Trondheim; , "The Potential for Location-Based Services with Wi-Fi RFID Tags in Citywide Wireless Networks". Proceedings of the 4th International Symposium on Wireless Communication Systems, 2007. ISWCS 2007. pp.148-152, 17-19 Oct. 2007 doi: 10.1109/ISWCS.2007.4392319

[5] Shi, W and Liu, Y.; , "Real-time urban traffic monitoring with global positioning system-equipped vehicles," Intelligent Transport Systems, IET , vol. 4, no.2, pp. 113-120, June 2010, doi: 10.1049/iet-its.2009.0053.

[6] Tarkoma, S., and Lagerspetz, E.; , "Arching over the Mobile Computing Chasm: Platforms and Run-times". IEEE Computer 2011 vol. 44, no. 4, pp. 22-28, April 2011, doi: 10.1109/MC.2010.272

[7] Lachapelle, G.; , "Pedestrian navigation with high sensitivity GPS receivers and MEMS". Journal of Personal and Ubiquitous Computing, vol. 11, Issue 6, August 2007, pp. 481-488, doi: 10.1007/s00779-006-0094-3

[8] Zheng, Y., Liu, Y., Yuan, J., and Xie, X.; , "Urban computing with taxicabs". Proceedings of the 13th international conference on Ubiquitous computing; ACM: New York, NY, USA, 2011; UbiComp '11, pp. 89–98

[9] White, J., Thompson, C., Turner, H., Dougherty, B., and Schmidt, D.C.; , "WreckWatch: Automatic Traffic Accident Detection and Notification with Smartphones". ACM Journal Mobile Networks and Applications, vol. 16, No. 3, June 2011 pp. 285-303, doi: 10.1007/s11036-011-0304-8

[10] Bellavista, P., Corradi, A., Montanari, R., and Stefanelli, C.; , "A mobile computing middleware for location- and context-aware internet data services". Journal ACM Transactions on Internet Technology (TOIT), vol. 6, Issue 4, November 2006, pp. 356 - 380, doi: 10.1145/1183463.1183465.

[11] Meier, R., and Cahill, V.; , "On Event-Based Middleware for Location-Aware Mobile Applications," Software En-gineering, IEEE Transactions on, vol. 36, no. 3, pp. 409-430, May-June 2010, doi: 10.1109/TSE.2009.90

[12] J. Kurose and K. Ross; , "Computer Networking. A Top-Down Approach". ISBN 0-13-607967-9 Ed. Addison Wesley 5th edition 2010

[13] Yu Zheng, Lizhu Zhang, Zhengxin Ma, Xing Xie, and Wei-Ying Ma.; , "Recommending friends and locations based on individual location history". ACM Transactions on the Web. Vol 5, No. 1, Article 5 (February 2011), 44 pages. DOI=10.1145/1921591.1921596

[14] Sung-Hyuk Cha; , "Comprehensive Survey on Distance/Similarity Measures between Probability Density Functions". International Journal of Mathematical Models and Methods in Applied Sciences. Issue 4, Volume 1, 2007, pp. 300-307