A Service Platform for Context-Aware Mobile Transport-Related Information Services

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Abstract – **This paper describes an architecture and implementation of the service platform for development of mobile information services to support fast, efficient and secure travel of people and transport of goods. These services are able to integrate, store and manage geo-referenced information related to traffic and transport and to deliver valuable functionality and content according to mobile user requirements, past, current and predicted movement and context.**

Keywords – **location-based, context-aware, mobile services, transport information systems, traffic management**

I. Introduction

With the recent advance and spreading of 2.5G and 3G mobile communication networks and development of new methods and technologies for mobile positioning, a huge interest in specialised mobile information services for support of various business, tourist and recreational activities emerges. Increasing demand for mobility of people and goods and dependence of modern economies on secure and efficient traffic and transport raises the importance of mobile information services that support safer and more efficient traffic and transport. Such services provide support for movement of users and transport of people and goods with aim to increase efficiency according to time, minimize resources needed (energy, financial, human) while, at the same time, decrease the risks of road accidents and minimize energy consumption and air pollution. Thus current research in intelligent transportation systems, such as EU ICT FP7 Challenge 6, addresses ICT for Intelligent Vehicles and Mobility Services [1]. Such services are designed for mobile users as support of their mobility and everyday activities. Their features, functionality, content and interface/interaction are adapted to users' past, current and predicted location and context.

II. Mobile Data and Information Services in Traffic and Transport

Advances in mobile and ubiquitous computing, wireless communications, mobile positioning and sensor technologies enable collection of huge amount of data about mobile objects. Such data represent movement of users and objects of their interest as a sequence of locations at particular time instants. They also represent the context in which such movement occurs and define user situation while accessing services. The context, besides location and time, includes mobile computing and communication features, time of day/week/year, weather conditions, light and noise levels, nearby people, objects and devices, user activities and goals, user profile and preferences, etc. If a user drives a vehicle, the context includes the telemetry vehicle data, such as speed, direction, fuel level, engine status, and other data acquired from integrated sensors. Such a huge amount of continuously changed and acquired location and context data requires adequate methods, tools and techniques for data management, [2, 3, 4]. Data management includes efficient representation, storage, retrieval, processing, analysis, exchange and visualization of data about mobile object and is integrated into a platform for mobile information service development [2, 5].

A service platform should provide efficient representation of contextual description of users/mobile objects movement, as well as methods, index structures and algorithms for query processing and retrieval of mobile data [2, 5]. The processing and analysis of movement data enable generation of dynamic travel times along the road segments and, based on them, detection of traffic jams and stops. Analysis of history of mobile object movement provides knowledge discovery from these data, detection of movement patterns and generation of movement profiles according to context in which such movement occurs [6, 7]. Acquisition of huge amount of useful movement and context data related to transport of mobile users/vehicles have given a rise to a new class of mobile and ubiquitous applications and services, that are aware of the location and context of user/object of interest. Such services are capable to adapt their behavior and functionality according to the context with minimal distraction of the user and are called location-based (LBS) and context-aware services. LBS and context-aware include applications like automatic vehicle location, fleet management, tourist services, transport management, traffic control and digital battlefield. Market trend reports forecast that in 2013 up to 200 million mobile users regularly use some kind of LBS and context-aware services with generated revenue to about 13.3 billion of dollars [8]. Modern location-based services for navigation and transport purposes available on the market can be two fold:

- Navigation services (e.g. TomTom[1], Garmin/SCG Route[2]).
- Fleet management (e.g. Euman A/S[3], FleetOnline™[4])

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[1] http://www.tomtom.com
[2] http://www.garmin.co.yu/
[3] http://www.euman.com/
[4] http://www.fleetonline.net/

The functionality of commercial services is mostly based on current location of user/tracked object and on static data about road network, without or with minimal use of dynamic, real-time data like dynamic travel times, traffic accidents, jams, road conditions, etc. Such services do not take into account the whole history of user/vehicle movement and the context which define such movement which define the situation of the users. Obviously there is a need for service developers and providers to provide appropriate integration and management of such data and delivery of mobile information services completely customized and adapted to past, present and predicted movement and context of users/vehicles [9, 10].

III. MOWIS SERVICE PLATFORM

MOWIS service platform represents foundation for development of mobile, location-based and context-aware information services. It includes support for data management about movement and context of mobile objects:

- Methods for representation and storage of mobile objects data representing user movement and context.
- Methods, techniques and algorithms for querying and retrieval of movement and context data.
- Methods and techniques for user/mobile object movement analysis and pattern recognition and prediction of movement and context.

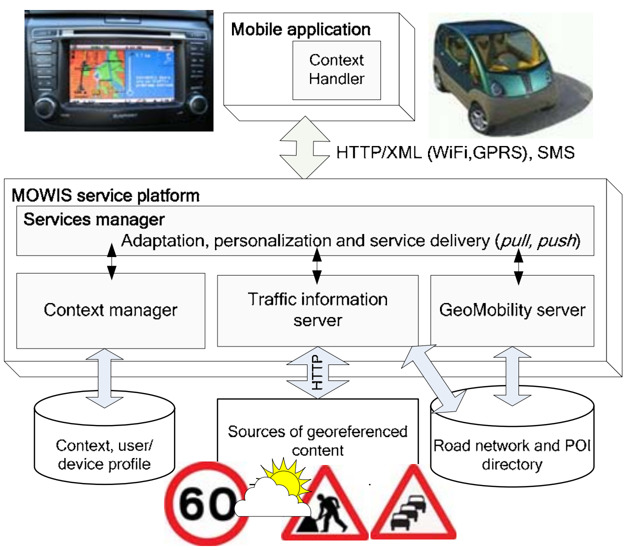

Fig 1. MOWIS service platform general architecture

Architecture of MOWIS platform includes following main components and is shown in figure 1:

- *GeoMobility server* represents implementation of OpenLS services for geocoding, reverse geocoding, routing, POI directory, presentation of information on mobile devices and gateway to location servers [11].
- *Traffic information server* integrates dynamic multimedia data (roads condition, weather forecast, traffic accidents, road segments under construction, traffic congestions and similar) from different sources with digital geo-referenced data representing road network. Access is enabled using standard interfaces and protocols like those defined by Open Geospatial Consortium (WMS, WFS, WCS) [12] and DATEX [13].
- *Context manager* provides acquisition, storage, transformation and interpretation of context data acquired from various sensors which finally results in complete description of user's situation. This server delivers context information to *Service manager* for the purpose of service adaptation and delivery either on user's request or on notification by *Services manager*.
- *Services manager* represents unified access point for MOWIS services and provides services adaptation and personalization in accordance with user's situation and context.

Service platform provides support for development of two major categories of mobile/Web information services supporting safe and efficient transport of people and goods:

- Mobile information services oriented toward mobile users, based on their past trajectory, current location and predicted movement, as well as users' context and situation.
- Mobile/Web information systems and services for tracking and monitoring of vehicles included in transport of people and goods with adequate selection of routes and means of transport.

IV. MOBILE INFORMATION SERVICES BASED ON MOWIS PLATFORM

The main objective of MOWIS service platform is to support development of mobile information services based on location and movement of user/mobile object of interest, their trajectories and their continually changing context. Based on MOWIS platform the users such services should be able to:

- see his current position, or position of every other vehicle being tracked over digital map on mobile device,
- show users' status represented by physical and computing context acquired from sensors attached to client mobile device, as well as vehicles' status obtained from vehicles' sensors,
- view vehicles' movement in real-time while maintaining minimal load on wireless network, server memory and processing resources of mobile devices and the server,
- obtain information and notifications about occurrence of unpredictable events concerning vehicle (user/vehicle has left defined route/area, remaining fuel low, speed exceeds maximum defined, user/vehicle is in vicinity of another object etc.),
- obtain information concerning road condition, occurrence of traffic jams and stops, accidents and roadwork, and based on them obtain alternative routes toward destination,
- analyze previously recorded and stored trajectories to support decision making in the process of planning transport of people and goods that are safer and more efficient.

Implementation of service platform started with the realization of *Traffic information server* and *GeoMobility server*. Java Servlet technology and Apache Tomcat Java application server was used for implementation and deployment. PostgreSQL database with spatial extension PostGIS was used to store geospatial data (roads network, addresses, points of interest – POI), as well as multimedia data referenced to road network. All services offered by *Traffic information server* and *GeoMobility server* were made available through XML protocol defined by OGC [11, 12]. The service chaining is enabled when it is necessary to invoke multiple services to process single, complex user request. For example, user requests routing service by specifying origin and destination as addresses. Before invoking routing service the system transforms origin and destinations addresses to points specified by coordinates by invoking geocoding service twice, for start and end point. Only after that system can invoke routing service in order to acquire optimal route based on current road network state.

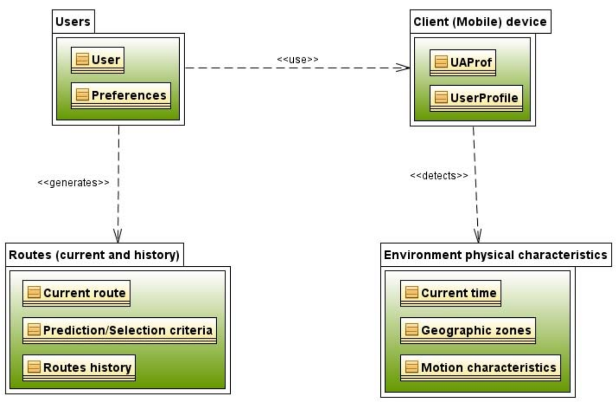

Fig 2. Context model used by MOWIS platform

Context manager implements components for acquisition, storage, processing and interpretation of user's context. Contemporary mobile applications almost exclusively interpret only technical characteristics of mobile device as context which represent only a subset of information that can be interpreted as context. Today, users of mobile applications move along the road network and have various sensors (location, lighting, noise, orientation, accelerometers etc.) integrated with their mobile devices. So the context of such users can be described much more accurately. Apart from mobile device hardware characteristics, user's profile/preferences and geographic environment, MOWIS platform includes routes as context information that characterize situation the user is in and the goal of his movement. (figure 2.)

An important component implemented as part of *Context manager* provides user's mobile device profile management – *DeviceProxy*. This component accepts initial request sent by the user. Considering the fact that typical users of the presented system employ various types of mobile devices the first step is to detect relevant technical characteristics of the employed device that affect service operation and deployment. Initial HTTP request to log onto the system contains some form of identification of the mobile device. Currently, there are a number mechanisms being used in the industry for this purpose, such as UAProf (User Agent Profile), WALL (Wireless Abstraction Library) or WURFL. UAProf, which is used in the MOWIS implementation, uses separate header in the HTTP request to provide link to XML document containing detailed description of hardware and software features of the device sending the request. These XML descriptions are maintained by mobile device manufacturers and, based on this information, the server decides whether to reply to the client with link to XHTML Web application, link to J2ME application to be installed OTA or link to download .NET Compact Framework Windows Mobile application.

After login, each registered user becomes a continuous source of positional updates containing also movement characteristics (speed, heading etc.). *Context manager* component which performs spatial analysis bases its functionality on known road network. This component generates a current user's route by matching received stream of positional updates to underlying road network. This component also generates and stores the histories of routes users take. The key issue in interpreting route as wider contextual information is matching current user's route with routes recorded in the history. If currently generated route is not matched to any route in the history, the system adds it to the history allowing the user to classify newly created route. Route classification ("going to work" and similar) is a basis for further reasoning about travel purpose and user's intent. If there is matched route in route history, the system uses matched route to predict user's future trajectory. It is important to emphasize that route matching takes into account not only spatial component of the routes being compared, but also time component, matching the time (time of day, day of the week etc.) when route in history was recorded and current time. Also, movement profiles, such as average speed per road segment and number of stops, represent additional weight factors for matching process and allow fine classification of routes in history. After the spatial analysis is completed, generated data (route ID, users' intent and similar) are included into a rule engine. Current MOWIS implementation uses JESS (Java Expert Shell) rule engine. The rule engine applies defined rules to the constantly changing set of contextual information contained in memory to generate contextual information at a higher logical level (user's state or intention). It also includes generated information in the rule engine to trigger appropriate *Service manager* action therefore adapting offered service to user's changing environment. The usage of general type rule engine like JESS makes *Context manager* flexible and enables dynamic registration and deletion of large number of rules and tracking requests. Thus is can appropriately react to context changes of high number of users. Apart from performance improvement this approach doesn't require frequent system restarts and initializations when additional rules are introduced. In the environment where the system tracks potentially large number of users procedurally based implementation would not be possible.

Services manager performs adaptation of services which are delivered to mobile users in accordance with their current location, past and predicted trajectory and the context. This component offers two service delivery models:

- Upon request, when client initiates interaction with *Service Manager* and requests services in accordance with his current/predicted movement and context.
- Notification by service, when *Service Manager* proactively initiates interaction with the user and delivery of appropriate service in response to occurrence of certain event, or fulfillment of defined rules over movement and context data.

a) b)

Fig 3. Mobile applications based on MOWIS platform a) navigation service b) public bus transport service

Based on presented functionalities two mobile information services intended for proof of the concepts and demonstration purposes have been implemented:

- Navigation information service enabling user to receive dynamic data concerning traffic conditions along defined route. These dynamic data include road status, meteorological data, and information about congestions, accidents and road work. User can subscribe to this service and either requests or be notified about occurrence of important events in accordance with his movement and context. Based on this information user can request alternative route which can lead him to the destination more quickly and efficiently (Figure 3a).
- Information service for tracking buses in public transport which provides prediction of bus arrival times (figure 3b) [9]. Users are able to receive this information either on request or by notification in accordance with his location, movement, context and interests.

V. Conclusion

MOWIS service platform and mobile information services based on it are aimed to support ICT solutions of problems caused by ever-increasing mobility of people and goods. These problems include traffic jams, congestions, fuel and energy consumption, pollution emission and above all increasing number of traffic accidents causing significant loss of life and material damage. Having in mind important role that transport of people and goods plays in modern society and economy it is reasonable to expect appropriate ICT support for safe and efficient traffic and transport. Further, service providers are able to offer users, individual or corporate, information services accessible by mobile computing devices connected to Internet/Web to improve their safety and efficiency in road transport. Individual users or corporations whose operations include transport of people and goods, can subscribe to such services and achieve significant savings in human, material and financial resources making their operations safer and more efficient. State institutions that manage and plan urban traffic will have opportunity to manage and plan future infrastructure development and maintenance for faster and more efficient traffic.

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