The UbiBus Project: Using Context and Ubiquitous Computing to build Advanced Public Transportation Systems to Support Bus Passengers

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Abstract. *The area of Advanced Public Transportation Systems (APTS) aims to investigate how to apply well-established technologies to support public transportation passengers by providing real time information that can assist them on planning their trips by choosing times and itineraries more appropriate to their needs according to the current availability of transportation. Our project, named UbiBus, proposes an APTS solution that integrates the concepts of Computational Context and Ubiquitous Computing on building more intelligent and available applications to support bus passengers on cities. It considers the mobility of people and vehicles and the occurrence of dynamic factors that could affect the transportation means and provide advanced information about the available bus transportation in a city. In this light, the paper describes the overall ideas concerning the UbiBus project, with its objectives and expected contributions, the applications under construction with their preliminary results and proposals for ongoing work.*

1. Introduction

Big cities are increasingly suffering from the problem of urban mobility. Several problems, such as constant traffic jam, lack of investments in road infrastructure, and poor quality of the services provided by public transportation makes the citizens daily life stressful and complicated [1]. Stimulating the use of public transportation is essential to support urban mobility, because it reduces the number of cars on public roads [2]. According to [3], the use of information technology for planning, managing, operating and monitoring public transportation has become a feasible alternative.

According to Sussman [4], Intelligent Transportation Systems (ITS) aim "to combine high technology and improvements in information systems, communication, sensors, and advanced mathematical methods with the conventional world of surface transportation infrastructure". APTS (*Advanced Public Transportation Systems*) is a subarea of ITS interested on providing passengers information and technologies to enhance public transportation system operations. APTS often involves situations and objects related to issues such as navigation, mobility and traffic, i.e., aspects that have greatly vary their behavior. Thus, APTS users need information about their transportation to be available "anytime, anywhere, from any device" [5].

Besides, understanding the current context of transportation vehicles, route, passengers and devices is an essential factor to assist those systems in achieving their goals. Static information, stored in databases, such as the ones related to the predetermined schedule of buses is not enough. Context information can be related to the vehicles themselves (e.g. current location, speed or availability), the route conditions (e.g. traffic jam, accidents, obstructions), time of the day (e.g. rush hour), meteorological conditions (e.g. rainy days, natural disasters), alternatives for integrated transportation, among others.

In our work we investigate the integration of concepts from Ubiquitous Computing [5] and Computational Context [6] areas into the APTS domain in order to develop a ubiquitous, context-sensitive advanced public transportation solution, called UbiBus [7]. Within our project, we aim to specify and implement technological solutions (e.g. models, algorithms and tools) to ease the access to information about public transportation, in particular urban buses. The applications being developed use real time dynamic context information collected from different sources, considering the mobility of vehicles and passengers, and dynamic factors that can affect the transportation. Different services are provided to passengers, such as route recommendation, estimation of location and arrival time, traffic occurrences registration and visualization, and so forth. These services can be accessed seamlessly from different devices (e.g. desktops, terminals on bus stops, displays inside a bus, or mobile phones).

The UbiBus project investigates different aspects related to: (i) the acquisition, processing and management techniques for context information either static or dynamic; (ii) algorithms and mathematical models to calculate travel times and to define better routes; (iii) techniques for visualizing and interpreting geographical information, considering large volume of data from transportation systems and routes; (iv) the development of a middleware to support building context-sensitive ubiquitous applications; (v) the development of different adaptable, context-sensitive, multi-platform applications to support passengers; and (vi) the development of route and transportation recommendation systems.

The focus of this paper is on presenting the overall ideas and preliminary results underlying the UbiBus project. The paper discusses related work in Section 2. It describes then the overall architecture of UbiBus (Section 3), the preliminary results achieved with implemented applications (Section 4). Finally, it presents our conclusions and perspectives for future work in Section 5.

2. Related Work

Several applications have been developed to assist users in finding out information about public transportation means in a city. Tools for mobile devices like OneBusAway[1] [8] and Waze[2] provide information according to the user's geographic location, achieved by GPS (Global Positioning System). Waze generates maps according to the route informed by the user, and presents traffic data collected in real time from other people who are also using the software [9]. OneBusAway is directed to bus users in Seattle and its vicinity, and presents all bus stops closer to the user's location, the lines associated to each stop and their current schedules, updated in real time by the bus company. OneBusAway also provides a web interface that displays a map with the bus stops' locations and the timetables for all vehicles associated to those stops.

Other available tools are based on the principle of visualizing information on maps. ToTransit[3] displays the map location of street-cars in Toronto, Canada, with information provided, in real time, by the transportation companies; and Bus Maps London[4] , which shows static information about bus stops, routes and schedules for the city of London. Google Maps[5]

[1] http://www.onebusaway.org/
[2] http://www.waze.com/
[3] http://totransit.ca/
[4] http://www.tfl.gov.uk/tfl/gettingaround/maps/buses/
[5] http://maps.google.com

also presents APTS features for some cities, enabling people to plan their routes using the public transportation system. Moreover, Google Maps APIs are used to compose most of the applications mentioned on this section.

Despite those initiatives, it is difficult to obtain dynamic information about public transportation conditions, since many unexpected events may occur in the route (e.g. traffic jams, accidents). Most solutions also strongly depend on the information provided by the official transportation companies and use proprietary methods and algorithms. Our proposal intends to build open source systems that could be freely available and evolved by the community.

3. The UbiBus Proposal

Figure 1 presents an overview of the UbiBus Architecture with its 5 main layers: *Data*, *Communication*, *Acquisition*, *Processing* and *Application*. The *Data Level* is responsible for managing the data processed by the system, including data representation, storage and retrieval. The database contains georeferenced spatial context for the trajectories of moving objects (e.g. buses, cars, subways, trains and people). Different data and information may be considered: bus location, bus speed, bus route, bus station location, passenger location, traffic jam information, maps and locations, lines and schedules, and others. Data on the positioning of mobile objects is continually updated, in order to represent their movements over time.

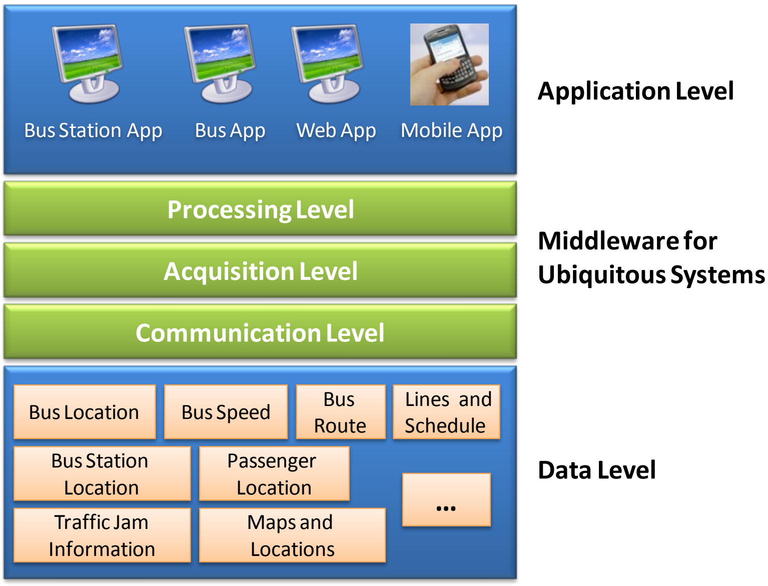

Figure 1. The UbiBus Architecture Overview [7]

The *Communication Level* allows the connection between static and dynamic elements that compose the transportation infrastructure, allowing information exchange in real time between managers, operators, users, drivers, vehicles and other elements surrounding the roads. The advances and standardization of wireless communication technologies (e.g. WiFi, Bluetooth, WiMAX) allows short and long-range communications. Information about traffic conditions and estimated time schedules may be offered directly to users, considering the wide availability of connectivity based on wireless communication technologies between mobile devices and laptops.

The *Acquisition Level* is responsible for gathering static and dynamic context information from different sources, sending them to the *Data Level*. Bus location and speed, for instance, can be acquired from GPS or RFID systems available on the bus or at a bus station; traffic information can be provided by cameras, social networks information, monitoring traffic systems or by inference using mathematical models; weather information can be provided by external meteorology systems; passengers' information (e.g. current location or next destination) can be provided by a personal mobile device or by the users themselves.

The *Processing Level* uses acquired contextual information along with mathematical and algorithmic solutions to calculate estimated bus arrival time. This layer is also responsible for pre-processing acquired information ensuring compatibility between different positioning systems (e.g. GPS and RFID) and the incorporation of semantics to the trajectories generated by mobile transportation units.

The *Application Level* contains the different types of applications developed on top of the UbiBus infrastructure. These applications should be adjusted to different platforms and devices (e.g. Web, desktop, mobile devices, terminals at bus stations or displays inside a bus). Features offered by each application process the data from the Data Level and provide up-to-date information to users regarding routes and buses they intend to use. Applications should be adaptable since different devices have different requirements and interface, usability and contents limitations and/or requirements.

Web applications enable an easy dissemination of the contextualized data related to traffic conditions. A web application should provide: i) arrival times for each bus at each station; ii) definition of the best route based on priorities (cost, time, comfort); iii) traffic level in each area, route or region; iv) time history of travels; v) map with the traffic intensity in different regions; vi) bus lines that pass at a given bus stop and bus stops available on a route; and others. *Mobile applications* have the great benefit of being portable, so that users can make a decision about their trip anywhere. Such applications are similar to web applications, but with interface adaptations for mobile devices and also the possibility of using the device's georeferenced position to generate more contextualized information.

Bus applications are terminals available inside the buses that provide information about their current situation. Passengers can, while inside a bus, visualize information about the trip and change their original plans due to unforeseen events. Some features that may be available in these applications are: i) estimated arrival times of the bus on each stop in the route; ii) previous and next stops; iii) traffic at each patch in the route; and iv) alerts for a bus station stop to aid disabled people. *Bus Station applications* provides information to the passengers that are waiting for a bus in a bus station about the buses s/he can take, the estimated arrival time of each bus and its location in a route map.

To support developing different types of applications, UbiBus proposes a multiparadigm, extensible and message oriented middleware for Ubiquitous Systems. It encompasses the activities presented on the *Communication*, *Acquisition* and *Processing* levels. A middleware plays an important role in developing context sensitive and ubiquitous applications since it facilitates the communication and coordination of distributed software components dealing, in a transparent way, with the difficulties and complexities introduced by mobility and wireless communication [10, 11].

4. Preliminary Results

This section presents an overview of the preliminary results achieved with the UbiBus project, concerning some developed applications, as described in the following.

4.1. Your City on Time

The Your City on Time (YCT) is a bus stop application that uses contextual information to estimate a bus arrival time at a given bus station. A map is used to contextualize the location data, whereas a table shows the bus lines that serve that bus station and the current distance and estimated arrival time for buses. The passenger does not interact directly with the system; they can only browse information that might offer some idea about the arrival time of the bus they are waiting for. That allows the user to plan their journey according to their next appointments. To calculate the estimated arrival time, the system considers contextual elements such as: bus identification, location, current speed and average speed; bus station location; route stretch average speed and traffic level. To infer the traffic level in a stretch we used two incremental weighted update formulas, proposed by [10]. The contextual elements *bus speed*, *bus location* and *bus average speed* are acquired using a GPS equipment by processing generated *NMEA sentences files*. The front-end application uses the *Google Maps* API[6] to provide directions and the distance between a bus and the next bus station in its itinerary.

3.2. UbibusRoute

UbibusRoute uses information coming from social networking sites (in this first prototype we have used Twitter[7]) to recommend routes to users, thus supporting them in their decision making processes. Based on the context of the user and of the route and buses, the application computes the possible routes (for each user to get to their destination), indicating on a map the route to follow. UbibusRoute was designed as a client-server application, where the client is a mobile application (that can work with any available operating system) that communicates with the server. The application counts with two Databases: one that stores Contextual traffic data, and another that stores Static Data pertaining mainly to public transportation. Static Data includes bus stops, bus lines and routes. The Server module is divided into three main components: the *Route Identifier*, responsible for identifying all possible routes according to the user's location or the selected bus stop; the *Route Indicator*, responsible for selecting the best route according to the user's preference (time, cost or distance); the *Contextual Information Extractor*, that acquires information from social networks and checks the current state of traffic. Additionally, there is a module (that wraps up the social networks) that works in capturing information related to traffic. The mobile application was developed over Android, coded in Java and uses some resources available on the Google Maps API. The UbibusRoute server was developed withe the framework Django[8] and all its modules were implemented in Python.

3.3. EPITrans

The Extraction, Processing and Inference of Transport information (EPITrans) is an application that offers updated and useful information to the users extracted from Facebook messages on a map. It exploits the cooperation between the Facebook social network users, by mining and extracting information related to the transit on the cities from the messages posted by users. A navigable map points the most current traffic events, informed by the users.

3.4. Occurrences reporting and visualization

To gather useful information among those textually available on Internet can be a hard task. Applications that use maps to show information can be an alternative to support the information visualization about facts that occur in traffic and affect the public transportation. We have proposed applications based on social network and crowdsourcing for this purpose. These applications aim to investigate and implement solutions and tools, which enable the access to knowledge of the crowd about public transportation conditions that are available on social network or another tools on Internet. These applications are described below:

- Collaborative routes editing: tool integrated to Facebook which enables users collaboratively to create routes. These routes can be visualized and edited by the

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6 http://code.google.com/intl/sv-SE/apis/maps/index.html

7 http://www.twitter.com

8 https://www.djangoproject.com/

contacts of the user. The application takes advantage of the collective intelligence power, because the contacts are responsible to create a route which meets the interests of the group that can use it [13]. In the future, the users will be able to indicate preferred routes, comment or give a reputation for a route that they used, and other features available on social networks.

- Occurrence report using mobile devices: it takes advantage of the mobility trend – by using cellphones, smartphones and tablets – to enable passengers to provide and get real time information about the public transportation that they are using. By using this application, users can report facts that occur in their route and retrieve the facts that affect a given bus line. The facts reported by users are posted via our application to Twitter. All the messages are retrieved by the application and can be visualized textually or in a map showing the most recent occurrences that can affect a given bus line.

- Occurrence reporting and visualization via web: aims to enable user to report occurrences using a collaborative map. The recorded occurrences are displayed as a pointer in the map, facilitating the identification of the occurrence location. The information about the occurrences are retrieved from a database that can contain information recorded by other UbiBus applications.

- Traffic conditions visualization: a web application based on maps that aims to display the possibility of traffic problems in a given location. The proposed application uses different colors in each section of a route, based on amount, intensity and type of messages reported. Thus, the application takes advantage of the power of the collective intelligence to show the possible traffic problems in a route.

5. Conclusions and Further Work

This paper presented an overview of the UbiBus Project, a multi-institutional initiative in the scope of smart cities, involving five institutions, being four universities and one information company, that aims to integrate methods and techniques from several areas (e.g. Ubiquitous Computing, Computational Context, Middleware and Geographical Information Systems) to build solutions for the advanced public transportation systems. This is a work in progress The paper also presented some preliminary results with developed applications. The project is at its beginning and several works will be developed on further work concerning the specification and development of the five levels indicated in the UbiBus architecture (Figure 1), the Middleware for Ubiquitous Systems and building additional applications regarding the Web, Bus and Mobile devices.

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