InfoBUS anyWhere - Mobile application for public transport use

André Levita, Ricardo Lopes Pereira, and António Brandão Leal
Technical University of Lisbon / INESC-ID / Tecmic

Abstract. InfoBUS anyWhere extends the Tecmic product XTraN Passenger designed for real-time monitoring of a public transportation fleet activity. InfoBUS anyWhere presents the information stored in XTraN Passenger to a mobile environment. Users can access arrival time prediction of transports or any kind of information regarding stations, schedules, transport lines, etc. The developed system also provides an automated process for planning a trip using only the public transportation network. This process uses arrival time prediction of transports and some preferences specified by the user to determine the most suitable plan. Users can then execute the trip plan in the mobile application and receive notifications or alerts of the trip details and occurrences.

Keywords: XTraN Passenger, Public transportation, Schedules, Predictions, Trip planner, Localization, Real time, Mobility, Context

1 Introduction

The widespread use of public transports at the expense of proprietary transport allows a reduction in terms of congestion, fuel consumption and greenhouse gas emissions [1,2]. However some people feel reluctant to use the public transportations due to its complexity or lack of information in proper places. The Advanced Public Transportation Systems (APTS) [3,4] provides more and improved information about this systems using information technology systems. One direct implementation of the previous system is the XTraN Passenger product developed by the Portuguese company Tecmic. It maintains real-time monitoring of a public transportation fleet activity by retrieving data from the vehicles such as its geographic location. It also provides information about arrival time prediction, stations, schedules, transport lines, etc. to users via Web, SMS, and electronic panels in some stations. Receiving this information in mobile context brings higher utility and use to the public transportation users.

Many users are faced with the need to move between places using public transports. The task of planning such a trip can become complicated and time consuming due to the range of available options and the need to consult all relevant information. The complexity increases when the trip plan involves the use of more than one transport line. Thus, to query information concerning stations, transfer points between transport lines and timetables to plot a trip plan translates into a difficult process and the possibility of the results being inadequate or inefficient in terms of time or total cost increases considerably. It is also impossible to contemplate that occur in public transports while manually conceiving the trip plan.
1.1 Goals and Solution

One main goal of this project is to provide mobile access to all available information from XTraN Passenger, taking in concern the user context. This will be achieved by developing a mobile application (InfoBUS Mobile App) where the users can request and graphically see all the information needed. The entire process for determining a trip plan must be automated, presenting to the user in the mobile environment, several alternatives for their displacement between a source point and a destination point. There should be considered two types of movement, pedestrian based and public transport based. The extensibility to other future types should be incorporated. Each trip plan will be constituted by a set of stations, schedules to comply and the public transports to use. To calculate the trip plans there are some factors to consider such as trip time, number of transfers between transport lines and pedestrian distance held. This entire process will be implemented on a different software component (Trip Planner Server) due to its complexity. After obtaining a plan from the Trip Planner, it should be possible to monitor its local execution. The mobile application will notify the user for each event occurrence such as the arrival of the user or public transport to a certain station.

1.2 Outline

This article is organized in sections: section 1 is the current section and presents a motivation to the topic and describes the goal and overall solution of this work. Section 2 presents the most relevant related work for this article. Section 3 describes the high level architecture and the system components. Section 4 presents the evaluation and section 5 is the conclusion of the article.

2 Related Work

The related work is presented by introducing some APTS. Some of them with Trip Planning functionality and Mobile Application interfaces. The last topic will be dedicated to the algorithms and data structures behind Trip Planning systems. Busview [5] is the first system universally available via Web that provides access to the geographic location of buses and a set of information relating to them. This system was extended by MyBus [6] to present arrival predictions of the buses in a mobile context through the Web but without any sense of user context due to the existing technology. Barbeau et al. and Patterson et al. present systems in order to help the movement of users with special needs in the public transport network [7,8]. The systems are composed by a Web interface and a mobile application. The routes are established in the Web interface and then executed in the mobile application with continuous notification and monitoring about user actions. This functionality is based on the user context, however, it is only possible to use the system with predetermined routes.
OneBusAway and Path2Go\cite{9,10} allow access to public transport information and provide a multi-modal trip planner to help the user trip to his destination. These systems have similarities to XTraN Passenger in terms of services provided to the user. However, its design is a little different because the information relating to public transports is located outside of the server infrastructure scope. Thus there is the need to access external services such as General Transit Feed Specification (GTFS)\cite{1} that provide the desired information.

NextBus\cite{2} and 511\cite{3} are other systems that also offer trip planning to a particular area of enforcement. They can be accessed via Web interfaces and mobile applications. However, unlike PATH2Go and OneBusAway, they don’t include a multi-mode simulator. Only one transportation mode is considered.

The existence of other platforms like Trimet\cite{4} and Google Transit\cite{5}, that only provide trip planning functionalities through a Web interface should also be mentioned. Google Transit operates over data files submitted in GTFS format. Depending on the region of trip, there may be more than one mode of transport. However, data used by Google Transit is static and doesn’t include delays or real-time arrival predictions.

Li et al. presents a trip planner that incorporates different modes of transport and real-time information\cite{11}. The design of the trip planner allows users specify some preferences regarding which modes they want to use for example. To determine the trip plans, it is considered the application of bi-directional algorithm Dijkstra\cite{12} and Jiminez and Marzal algorithm\cite{13} for the shortest paths considering the minimization of trip time as the main factor. The data model used is characterized by a transit network where there are different types of nodes (bus stations, car parks and transition points) and arcs/edges between nodes with temporal attributes that are updated periodically.

Jeral Jariyasunant\cite{14} algorithm considers the real-time arrival predictions and data collected from external sources to construct the transit network. It is not sustainable to get all needed data at once for each user request. This could result into a long delay between the request and the response to the user. The solution is to perform a pre-computation of required information and access the real-time data at runtime. For the trip planner component, there is another pre-computation that results on the creation of tables that consider all stations as a possible point of origin and per each one, every other station is considered as destination point with a maximum of four transitions between transport lines made along the path.

### 3 Components

The solution includes a client-server architecture. The components of this architecture can be separated logically by its functionality and location: server side and

---

client side. The server side contains the new developed component Trip Planner, the InfoBUS Server and the XTraN Passenger module. This InfoBUS Server is responsible for providing external Web access to all supported functionalities and information from the XTraN Passenger and the Trip Planner. It was developed by the Tecnic and it was extended to add more Application Programming Interface (API) in order to request Trip Planner services. On the client side is a mobile application that can access InfoBUS Server in order to obtain XTraN Passenger information or Trip Planner services, external road maps repository and Global Positioning System (GPS). The use cases defined for this application are specified in figure 1.

3.1 Trip Planner

The Trip Planner component determines trip plans based on the information provided by the user, i.e., origin, destination and preferences (fastest or fewer transfers between transport lines and pedestrian distance limit). The algorithm for obtaining the best trip plans relies on applying a shortest path algorithm on each of its iterations. For this purpose it was chosen and adapted the Dijkstra’s algorithm due to its complexity $O(|E| + |V|\log|V|)$ and execution time.

The information regarding stations and transport lines is obtained through the XTraN Passenger and is converted into a directed graph that represents the transit network. The nodes of the graph are stations and the edges/arcs represent the transport lines or pedestrian connections that make the connection between two nodes executable. Within this scope, the arcs used by the algorithm will be weighed according to the total trip time or the number of transfers between transport lines occurring, according to user preference. The weight of the arcs can only be allocated at run time of the algorithm since they are dependent on the time of arrival to the respective station or transport line previously used.

After the complete execution of the best trip plans algorithm, an access to the XTraN Passenger’s Time Estimating Server is made in order to obtain arrival predictions of the transports included at the previously calculated trip plans. If there are delays that alter the total time of the trip plans, a reordering of results is made. It is also possible that a trip plan becomes unavailable due to delays predicted. To avoid constant access to the XTraN Passenger in order to construct the transit network on each request on the Trip Planner, the transit network is computed with the application start-up, maintained in primary memory in order to reduce access times and updated in a given period $T$. The frequency of changing or inserting new data on stations, transportation lines or schedules should set the update period $T$, and this value is configurable by the administrator of the application.

3.2 Mobile Application

The mobile application is the only component where there is direct interaction with the user, thus serving the full purpose of the entire system. Through this application it is possible to execute all the use cases described in the figure 1. The mobile application is responsible for creating and transmitting the user requests
Fig. 1. Mobile Application Use Cases
to the InfoBUS Server. The results are then presented to the user graphically. These requests can obtain data from the XTraN Passenger or the Trip Planner. Much of the data obtained are combined with geographic maps obtained from external sources leading to a better comprehension of information by the user. Another essential service to this component commonly used in mobile environment is the GPS. The mobile application uses the GPS to facilitate some features, such as the location of stations nearby. Figure 2 shows some images from the Mobile Application.

![Fig. 2. Mobile Application Images](image)

The functionality of real time monitoring of a trip plan execution requires the use of GPS to compare the current position of the user with the route to accomplish. Additionally, there are also made requests to the InfoBUS Server for the current position of transports belonging to the execution plan. This functionality is implemented through a state machine where each state is related to the conditions of the user, i.e., waiting for transportation, walking to the station or the destination and on-board. The final state is represented by the user arrival to the destination. The transitions between the different states correspond to events like the station arrival, transport arrival or arrival at destination. This functionality operates in two modes: presenting continuously GUI so the user can see his location and context; running in background without continuously interaction with the user but still informing the user of the transitions that occur in the trip plan.
4 Evaluation

During system development, unit tests were performed to ensure the correct implementation of all requirements and functionality. The data used in XTraN Passenger refer to the geographical area of Chapecó, Brazil. In this section we present 2 important tests, one for the Trip Planner and one for the Mobile Application. The Server machine where the server side components were deployed is a Intel Core i7 840QM@1.87GHz processor with 4098 MBytes DDR3 RAM.

4.1 Trip Planner Requests

The execution time of the best trip plans algorithm is a crucial factor to evaluate the Trip Planner. The success of this component is based on its ability to present the best trip plans on acceptable time for the user, regardless of the diversity of input values. The input data for this test was randomly generated in order to simulate different conditions: point of origin and destination (within the geographical boundaries of the zone Chapecó, Brazil), date of departure (between 8 and 23 hours of 21.08.2012) and pedestrian maximum distance (between 500 and 1000 values). This test does not include the second phase of the algorithm, i.e., combining the results with the arrival prediction of transports at stations. Each request was duplicated to be processed as having preference for fastest trip in the original request and the trip with least transshipments in the duplicate request. 100 experiments were performed under these conditions. The chart of figure 3 presents the algorithm execution time of each application respectively. The results show an average of 74 milliseconds for the implementation of the algorithm having with total trip time as the heuristic and 93 milliseconds for the trip with least transshipments. There are however some cases where the algorithm execution time reached maximum values of 896 and 1107 milliseconds. Such cases can be justified by the need to explore all nodes and all possible combinations of connections between them and not finding any feasible route with the pedestrian distance specified.

![Graph showing trip planner requests](Image)

Fig. 3. 100 Trip Planner Requests
4.2 Usability Test

To evaluate the usability of the mobile application, 10 users were asked who have never had prior contact with the application. They performed a set of tasks that match the execution of defined use cases. Each task was evaluated according to the following metrics: time, number of errors and satisfaction (1-Very unsatisfied, Unsatisfied 2-and 3-Satisfied, 4-Good, 5-Very Good). The tasks are:

1. Perform an advanced search to go to the site: Chapecó - Santa Catarina, Brazil. Get the stations in the area shown. View detailed information about one of the stations obtained by the above process.
2. Make an advanced search for the transport line: 02-Tomazelli, Tomazelli. Direction: Down. Show current transports in the itinerary and find information for one of the vehicles illustrated.
3. Simulate a trip with the following data: point of origin and destination specified by the map and within the limits of Chapecó, select the date 24/08/2012 at 09:00 am; fastest route, and maximum pedestrian distance of 750 meters. Get results and consult the detailed plan for the first trip plan obtained.

Test results are expressed through the figure 4. The 1st task took an average of: execution time - 78.2 seconds; mistakes - 0.6; satisfaction - 4.2. The 2nd task took an average of: execution time - 83.4 seconds; mistakes - 0.3; satisfaction - 4.2. The 3rd task took an average of: execution time - 150.5 seconds; mistakes - 0.2; satisfaction - 4.8. On the whole, users were able to complete tasks without needing any help, understanding intuitively what to perform in the application. In some cases, they made mistakes that delayed the completion of the task. Some of these errors were: wrong navigation menu or selecting the wrong feature in the first attempt. In the specific case of the 5th user of the 2nd task, he did not find the functionality of displaying current transports in the itinerary. In common users opinion, all tasks contributed to a very positive satisfaction. The 3rd task, although the most extensive, was less error prone and had the best satisfaction average.

5 Conclusion

We extended the XTraN Passenger system to support Trip Planning functionality and created a new mobile interface for the system. The Trip Planner operates over data provided by the XTraN Passenger and determines trip plans taking into account real-time arrival predictions and some user preferences. The mobile application offers a GUI in order to intuitively request and view all the pretended information of the XTraN Passenger. The Trip Planner is achievable through the mobile application and it has the capacity to real-time monitoring the execution of the trip plan presenting event notifications to the user. The results of the evaluation show that the objectives and requirements were met. The users were satisfied with the mobile application prototype.
Fig. 4. Usability Test Results

References

10. Liping Zhang, Jing-Quan Li, Kun Zhou, Somak Gupta, Meng Li, Wei-Bin Zhang, Mark Miller, and James Misener. Traveler information tool with integrated real-time transit information and multimodal trip planning. pages 1–10. 2011.


