Personalized Mobile-Assisted Smart Transportation

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***Abstract*—Digital media covers larger parts of our daily lives nowadays. Mobile services enable a better connected society where citizens can easily access public services, discover events, and obtain important information in the city. We observe the popularity of mobile car sharing applications, such as Uber and Didi Dache. Mobile social applications provide new ways of developing and optimizing public transportation. In this paper, we present a mobile platform for timetable-free traveling. It can capture the traffic demand of citizens in real-time, and support efficient planning and scheduling for vehicles on-demand. At the moment, the platform is targeted for public bus services, but it has great potential to be extended for self-driving vehicles in the future.**

Keywords—smart transportation, mobile services, on-demand

I. Introduction

In modern society, sensing and mobile devices are available everywhere to gather data about the environment and human activities, which stimulate novel smart city applications. Mobile applications are getting increasingly popular nowadays. For example, smartphones are equipped with a wide range of sensors and communication modules. The GPS on the smartphones is used to monitor the locations of vehicles and predict the traffic flow and travel time in the city. The sensor data collected by mobile sensors at different times and locations can be aggregated to build a traffic map representing the traffic demand of the city for better city and infrastructure planning. Mobile applications are developed for citizens to plan for their routes, obtain schedules of buses and trains, and even show which train compartments have more empty seats.

This paper stems from a desire to optimize the process how bus schedules are generated in public transportation. At the moment, many bus companies have rather fixed timetables. The bus schedules are rarely updated, while the most frequent ones are updated every once or twice a year. We have been discussing with a local traffic company in Uppsala, called Upplands Lokaltrafik (UL). This bus company owns 375 buses and services the entire population of Uppsala, the fourth largest city in Sweden with a population around 210,000 residents in 2015.

The aforementioned bus scheduling system has a number of distinct limitations:

• It does not consider the personal needs of individual users. The user is expected to adapt their needs according to the provided timetable and not vice versa.

• It has limited consideration for the bus load. In fact, even though bus companies deploy more buses during busy hours, there are times during the day where some buses are still bound to be full while others are empty and driven through the city for no reason at all.

• The bus routes are static, which means that many buses might pass by an empty bus stop several times during the day.

These three disadvantages lead to excess costs, in terms of fuel and working hours. We formulated the problem and organized a course project with a team of master students in Uppsala University. This project attempts to address these issues by having a system that can dynamically allocate buses and create timetables according to the demand of the users. The possibility of dynamically changing a bus route is also considered within this project in order to reduce the cost and travel time.

II. Related Work

There are increasing number of trip planning services that suggest public transport routes to users with timetables and other information. Many of them are integrated with real-time data about travel times, which can be combined with information platforms based on crowd-sourced information [1], including traffic congestions, train signal failures, etc. Recently, car sharing of taxis or private vehicles has become increasingly popular. Mobile services are developed to allocate a suitable taxi or shared car to each trip in isolation. Such mobile services can be considered as an extension of existing taxi calling services. They utilize techniques for finding a suitable ride among a set of candidate vehicles based on certain criteria [2]. A number of global planning mechanisms have been investigated, such as heuristic mechanisms for the load-balancing of available taxis to serve expected future demand with lower latency [3].

Uber [4] is a mobile application similar to the taxi calling system which enables users to request drivers in order to be transported. Traditionally, one who wants to call a taxi, usually has to make request to a call center. With the Uber mobile application, everything becomes easier and faster. One can request a car online, then keep track of the car's GPS location on a map until the car comes to pick one up. The application gives a fare estimation for the ride, so that the user knows the price in advance. Finally, the user can pay easily through the app so the need for cash is eliminated. Uber also gives users the opportunity to give feedback after a ride.

Kutsuplus [5] is another bus service transport system deployed at Helsinki in Finland. The concept has been developed by Ajelo and is quite similar to Uber but instead of getting a cab on-demand you get a bus on-demand. A user requests a bus on a mobile application choosing the starting point, the destination, the departure time and the number of seats you want to book. Kutsuplus will then look for other people requesting a bus to the same destination and will propose possible routes. Once the trip is confirmed, the user can pay directly through the mobile app with a virtual wallet. The price is not fixed as in regular bus transit. For each trip proposition after a request, the fare is indicated. The fare can be split and becomes cheaper if one books a bus for a group. Ajelo was a startup company that developed the algorithm and was acquired in November 2014 by Split [8] to deploy a shared ride service in the United States.

Digital media further advances real-time monitoring of traffic flows and road conditions, in order to predict traffic patterns and detect emergencies. Integrating sensing and mobile technology into transport systems can improve efficiency and safety, as well as enable future applications, including autonomous vehicles. We expect more advanced mobile information services to be developed for intelligent transport systems to reach their full potential [6].

III. MoNAD System Design

In this paper, we present MoNAD [7] (Mobile Network Assisted Driving). Similarly, to most public transportation systems, it comes with an Android application, where the users of the system are able to request a bus by searching for a bus journey with a desirable date, time and location. As opposed to common public transportation systems, the user requests are collected and processed daily by the back end of the system to generate new dynamic routes, flexible timetables and personal trip recommendations. The back end system includes different functionalities, such as authentication, request handling, travel planner, recommendation, and the look ahead function to predict user demand dynamically. This is what makes MoNAD unlike any of the existing systems. In addition, an application is provided for bus drivers in order to display the route that should be followed by a specific line at a specific time of the day.

Two MoNAD mobile applications are used in order to communicate information between application users and the company. The Client and Vehicle Applications are designed for the passengers and the drivers, respectively. Usage of these two applications is very important in order to reach MoNAD's goal of improving bus timetables, which will optimize routes and reduce the passengers waiting time.

The Client Application presents information to the user, including but not limited to: personalized trip recommendations, a bus search function, and notifications. The Client Application also collects information from the users, such as requests the users make, in order to improve timetables, optimize routes, reduce passengers waiting time, and recommend interesting routes.

The Vehicle Application presents information to the drivers, including: information about routes, the maps to follow, and the number of passengers expected to board and leave at each stop. Additionally, the Vehicle Application collects information from the drivers, such as alerts about accidents which have affected the routes.

A. Client Application

The main feature in the Client Application is the ability to look for the best option to reach a destination. The Search feature is presented in two variants: The Quick Search bar and the Advanced Search screen. Both alternatives offer a list of addresses and bus stop suggestions to the user when entering the origin and destination.

Quick Search allows users to look for the optimal way to reach a destination starting from their current position. Since it is intended to save time for the user, Quick Search is accessible from the main screen of the application, and disregards all the other criteria that the advanced search provides as well. The system saves the user's location and uses it along with the entered destination to search for the appropriate bus line. The returned results are first sorted by relevance, then by the starting time of the trip. At this point it is important to note the system will monitor the user's location only with his/her consent.

The Advanced Search, on the other hand, gives the user full flexibility and control over the information that they would like to specify. First, the user has two options when selecting the starting point. Either the current position can be selected by pressing the pinpoint button or the user can begin to type the name of the bus stop and a list of suggestions will become visible. The destination can only be selected by typing and selecting a suggested bus stop. Next, the user has to enter the time and date of the trip. This can be done by entering either the departure or arrival time, which is ultimately the user decision as well. Finally, the user can choose between the earliest and the shortest trip where the earliest trip will look for the trip with the earliest departure or arrival time and the shortest trip will give more importance to the trip with the smallest duration.

B. Vehicle Application

The Vehicle Application is the second component of the MoNAD system, which is supposed to be run on a tablet sitting in front of the driver seat on the bus. While the Client Application is intended for customers to search and join trips, the main objective behind the Vehicle Application is to serve as an assistant of the driver during a bus journey.

The application tracks the location of the bus and displays the position in real time on the map. This, in turn, allows the application to update the distance and time left to reach the next bus stop in real time, which is displayed similarly to a GPS navigation system. Figure 1 shows a screenshot of the vehicle application. In addition, whenever the bus reaches a bus stop, the application updates the name of the next destination (i.e. bus stop), the estimated number of passengers boarding or leaving, and the estimated time of arrival.

The complete schedule of the journey can be accessed from the button with a bus icon on the side bar (see Figure 1), which is shown as a list of bus stop names with their respective expected arrival time. The two other buttons on the side bar are used to communicate with the system. One button shows a list of notifications and updates, while another button allows the driver to quickly send an emergency notification.

The emergency system is simple and follows the same aforementioned safety principle, as it gives the driver the choices to report different types of emergencies, and if necessary, to add a short description of the problem.

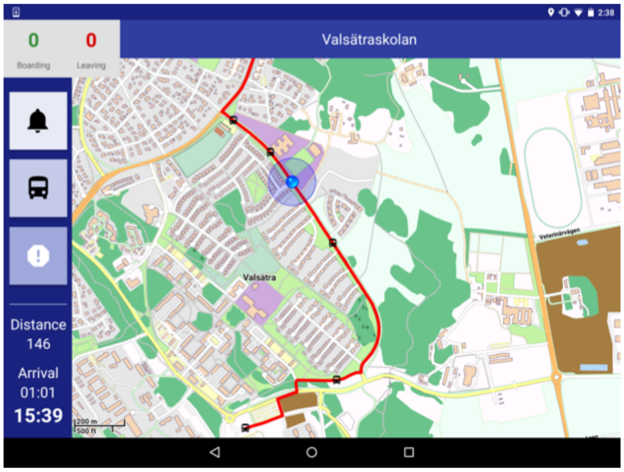

Figure 1. Screenshot of the vehicular application.

Nowadays, there are many APIs that are available on the Internet to get real-time traffic information such as construction, congestion, accident and so on. All these kinds of information could be helpful in the application to avoid wasting travel time and make a better bus schedule. The purpose of using real-time traffic information is to provide more precise estimated driving time (EDT) for the bus drivers. For example, if the bus goes through a heavy traffic congestion road, the EDT provided by the map will be updated.

C. *Travel Recommendation*

One component to improve the user experience is the Travel Recommendation engine. Based on observation that users tend to follow certain patterns when travelling, their request information (i.e. departure and arrival location and time) is collected and stored in the system and periodically processed. Requests that have similar characteristics represent a user's habit. The system then tries to match the user's needs based on his habit with the current timetable, so as to give better recommendations.

The goal of this module is to learn from every user's past behavior, then be able to distinct whether some trips are going to be of particular interest for him/her before giving suggestions. As soon as the user logs in, the application displays a list of suggested trips that is possible to select from without the need of searching it.

In a concrete scenario, a traveler who lives in Flogsta (western outskirts of Uppsala) with his workplace close to the Central Station is expected to request a bus every morning at around 8 am. After certain number of requests on repeating days, the application recognizes that this is a habit and can proactively list a number of trips that will cover this user's need, or even explicitly notify the user early enough to avoid missing the bus. This way, the application saves time for the user from configuring a search and browsing the timetable, and in the end offers a more personalized approach to the user.

IV. Conclusions and Future Work

In this paper, we presented MoNAD as a mobile platform that intends to improve existing public bus transportation systems. Making the system revolve with the behaviors of its respective users is both challenging and rewarding. We presented the prototype application developed by a student team in a course project over three months. The prototype provides some interesting results and insights for future research in the field. For future work, more efforts could be devoted to completing the prototype into a fully-deployable system for real-life interaction. A significant part of these efforts could focus on improving the compatibility of the Android applications and data reliability. In order to better understand real-time challenges, a trial can be done in large scale.

Acknowledgment

The authors would like to thank the students who took part in the Project CS course in the Department of Information Technology, Uppsala University, Sweden in the fall of 2015 and our industrial collaborators at Ericsson Research Sweden.

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