TRIPZOOM: A System to Motivate Sustainable Urban Mobility

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***Abstract*—The accelerating growth of cities provides new challenges for urban planning, especially related to transportation. Many existing infrastructures already operate at their limits during rush hours or large events. They need to be used more efficiently as they often cannot be extended without considerable negative effects for citizens such as increasing pollution or travel costs. We describe a framework that enhances mobility data from existing urban infrastructure with data from participatory sensing. Based on derived mobility patterns and direct feedback via social networks, a dynamic incentive system is provided to positively influence mobile behavior on a personal and city-wide scale beyond regular urban planning. We present the design and architecture of such a system and point out critical issues and proposed solutions in an initial implementation aimed towards real world tests in several cities.**

Keywords - sustainable traffic; urban mobility; personal mobile sensing; incentives; social networks.

I. INTRODUCTION

Today, more than 50% of the world's population lives in cities and the UN forecasts a further increase to 70% by 2050 [1]. This *metropolisation* creates many challenges for the world's cities [2]. Current transport infrastructures often cannot cope with the load anymore especially during peak times. They have to be used more sustainably as extensions incur considerable negative effects for citizens such as increasing pollution and direct or indirect travel costs.

The European FP7 project "Sustainable Social Network Services for Transport" (SUNSET [3]) is developing and evaluating the TRIPZOOM system [4] that implements a new approach to urban mobility management. The assumption is that sharing personal mobility patterns via social networks and the use of incentives can encourage citizens to utilize sustainable forms of transportation and to generate a win-win situation for all involved stakeholders (Fig. 1). Citizens can optimize their mobility needs using recommendation and personalized traffic services from the city authority, share travel related information with buddies on social networks (like the community-based traffic app WAZE [5]) and get rewarded for sustainable behavior. The city authority receives detailed mobility profiles of citizens, relevant to the assessment of current infrastructure use and future mobility needs, and achieves optimizations by offering incentives. Communities, like employees of a company or participants of a car sharing system, are supported in networking and in enlarging their groups. Third party service providers can tap into the data to create novel offerings and integrate with others through common incentive structures (like the location-based incentive application FOURSQUARE [6]).

To reach the project goals, we are realizing a technical and socially supportive environment called TRIPZOOM that complements urban infrastructure sensing with participatory mobility sensing. TRIPZOOM is based on our competences gained by developing and operating the context-aware community application IYOUIT [7], the mobility capturing application TRAVELWATCHER [8], as well as the traffic jam alerting application FILEWEKKER [9]. In contrast to other real-time mobility monitoring systems focusing on anonymous, aggregated data (such as [10]), TRIPZOOM generates detailed personal mobility patterns. These allow users to zoom in on trip details and raise awareness by computing trip overviews and eco feedback [11] that can be shared with friends or the community.

It is often assumed that direct feedback can positively influence the mobility behavior of individuals and that social influence is probably the most powerful factor behind human behavior change. We will use the TRIPZOOM system to evaluate these assumptions and to develop feasible and successful incentives by operating living labs in three European cities.

In the following, Section II describes the incentive and social networking aspect on which TRIPZOOM is built. Section III highlights important aspects of the mobile sensing part while Sections IV and IV provide details about the architecture and implementation. We conclude with a description of the current status and next steps within the project.

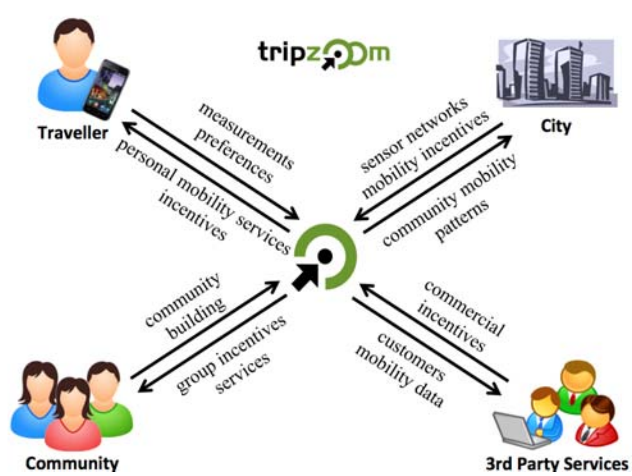

Figure 1. The TRIPZOOM eco-system.

II. INCENTIVES AND SOCIAL NETWORKING

TRIPZOOM aims at providing different types of incentives to relevant target groups at relevant places and in relevant situations. To incorporate the most effective types of incentives, we conducted an analysis of individual travel behavior [12]. This research implies that influential incentives should be based on the following areas:

- *Time:* efficient use, control, saving, and planning
- *Money*: save (e.g., discounts on transportation tickets) or even generate (e.g., coupons)
- *Information*: receive (real-time, personalized) information about progress, travel alternatives, …
- *(Social) recognition*: of being green and healthy/fit; give feedback to and receive feedback from others

In TRIPZOOM, incentives appear mostly in form of a challenge defined by a set of rules that users have to fulfill and a reward that they can earn (e.g., take the bike instead of the car to get a coupon financed by a bicycle store). To be able to evaluate the effect of different (combinations of) incentives, TRIPZOOM offers dynamic and controllable incentive management. It allows for generating and placing incentives in real-time during the entire runtime of the system. This means that weak or unintended side effects of incentive offers [13] can be detected early and that incentive operators such as city representatives can alter incentives accordingly.

For this purpose, a component called city dashboard (see Section IV) is being developed that will offer a live view on various aggregated statistics and anonymized data of the users within a city. It can be used to efficiently check and evaluate the effect of incentive measures. This approach can be used to change overall mobility behavior (e.g., fewer cars in the city) or to target specific goals, e.g., optimizing the use of alternative travel modalities before and after large events.

TRIPZOOM uses a point scheme as one way to integrate various offers, and to open the incentive system to third parties: each incentive is worth a certain number of points, which can be exchanged for certain rewards, for example information or monetary items such as access to fare reductions. This point scheme also makes it easier for users to track their progress as well as to share and compare it with friends and colleagues (Fig. 2). This adds competition as a gamification feature [14] and creates a more playful experience. For that purpose, TRIPZOOM offers a set of social networking features that connect to popular sites such as FACEBOOK, FOURSQUARE and TWITTER. That way, existing social networks are used to advertise TRIPZOOM and to allow users to share their progress and achievements with others. These social connections can themselves be seen as a powerful tool for inducing behavior change as people can engage in competitions. Furthermore, all users' privacy and sharing settings are defined with respect to their connections.

III. MOBILITY SENSING

To optimize mobility, one needs to identify individuals that are relevant for the optimization targets under consideration. Therefore, mobility sensing plays a fundamental role in the proposed TRIPZOOM system. To gain profound insight into mobility behavior, TRIPZOOM combines the strengths of two orthogonal approaches: infrastructure sensing that measures vehicle intensities or travel times in urban networks (e.g., roads, rails, bus lanes), and personal mobility sensing that uses mobile phones to track how citizens make use of that network.

Infrastructure sensing includes traffic light and intersection status providing information about traffic intensity, intervals of traffic light phases, and delay times. License plate cameras can estimate dynamic travel times on the roads between any two cameras. Parking areas deliver information about the number of total and available lots. Further data can be real-time public transport information such as the actual location of buses. Infrastructure data is often limited in geographic coverage, and has restricted possibilities to track individuals throughout the whole transportation network.

Personal mobility sensing uses various technologies in citizens' mobile phones (e.g., GPS / Wi-Fi / accelerometer [8]) to detect or deduce the 4 Ws of personal mobility: **w**hen do people move, **w**here (via which route), with **w**hom, and using **w**hich modality (bike, car, etc.). While personal mobility data allows detailed individual tracking, only a small part of the city community can be expected to participate. Still, the goal is to get an overall mobility profile per citizen (Fig. 3) covering a 24/7 period. The use of mobile phone sensors and battery power has to be carefully balanced with the measurement accuracy to be achieved [15].

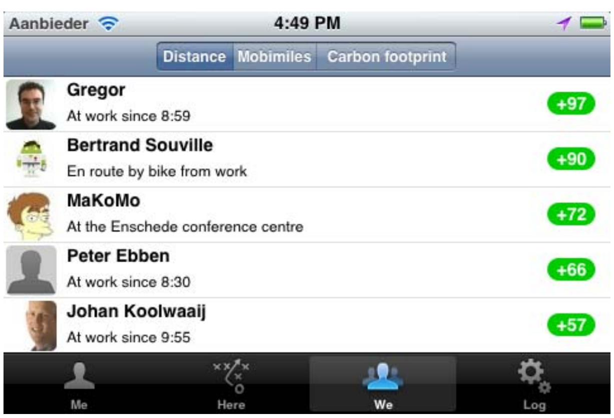

Figure 2. Buddy list including current incentives points.

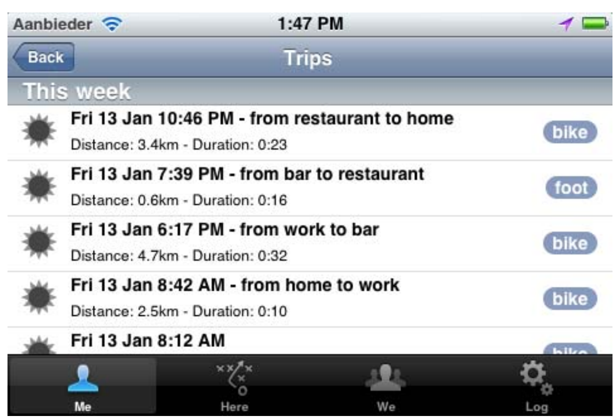

Figure 3. Trips and detected modalities.

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Combining and correlating both approaches relieves these shortcomings by improving the level of detail regarding the geographic and community coverage of the TRIPZOOM measurement approach.

IV. ARCHITECTURE

TRIPZOOM consists of a network of Core Services guarded by Proxy and Security Services. Mobile clients, a web portal, and the city dashboard act as interfaces to the user. Furthermore, a social network infrastructure allows for easy sharing of data (see Fig. 4 and detailed description in [16]).

The service infrastructure delivers incentives (see Section II), mobility monitoring (see Section III), and basic social network services. The security layer allows access to the TRIPZOOM universe only according to user consent.

The mobile application supports sensing of personal mobility by connecting to (sensor) data such as mobile phone location information and offers a means to interact with the user. The Web portal additionally provides visualizations of statistical data as well as comparisons with respect to community mobility patterns. Traffic authorities and researchers use the city dashboard to get an overview of the current mobility situation and have control over applied incentives.

Additionally, TRIPZOOM uses resources offered by external or third party components, e.g., sensors and services to monitor road traffic and to obtain public transportation status information. In the same way, third party applications can request access to services provided by the system components depending on user consent. Six components provide the core service functionality.

Personal Mobility Store (PMS): collects raw measurements from mobile clients and preprocesses them to be input to algorithms such as pattern detection.

Mobility Pattern Detector (MPD): receives data from the PMS and employs sophisticated algorithms to detect patterns for individuals, groups, places, regions, routes, or vehicles such as bus lines or a taxi.

Mobility Pattern Visualizer (MPV): takes the patterns derived by the MPD and turns them into interpretable and easily accessible visualizations depicting long-term statistics, trends and personal, city-wide, or place-oriented performance with respect to set goals.

Relation, Identity, and Privacy Manager (RIP): provides its own social network implementation and organizes the privacy policies of users based on their social relations or ad-hoc groupings computed by the MPD.

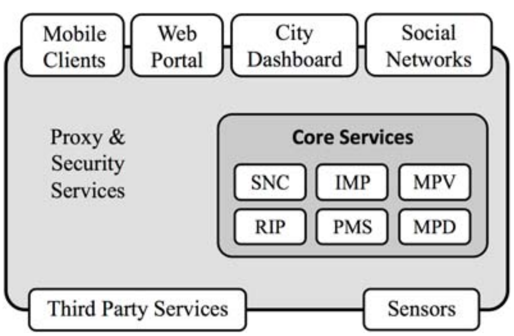

Figure 4. Main system components.

Social Network Connector (SNC): connects the internal social network (RIP) with existing social networks such as FACEBOOK or FOURSQUARE, to facilitate user registration, information sharing (e.g., a notification on the successful completion of an incentive), importing contacts, or showing visualizations from the MPV.

Incentives Market Place (IMP): provides a platform for incentives as rewards, recognition, or real-time feedback to encourage travelers to improve their behavior with respect to the system's and individual's objectives. The IMP matches challenges with mobility patterns from the MPD, profiles and preferences from the RIP, general transport information, and can publish performance and events using the SNC.

V. IMPLEMENTATION

The distributed system is implemented building on Representational State Transfer (REST) and JavaScript Object Notation (JSON). This supports loose-coupling between the components, clear interfaces, and independence of platform and programming language. The security layer uses OAuth [17], a simple mechanism to publish and interact with data that needs access control. It is wide-spread and used by many systems such as FACEBOOK or TWITTER. The TRIPZOOM social network features such as the Social Network Connector build on the open source social networking engine ELGG [18] Using such a platform has the advantages that users are not required to use a specific network and it simplifies the integration with other functionality that the portal and mobile application offer.

A. Mobile Client

Information from mobile device sensors (GPS, Wi-Fi, and GSM measurements) is combined into one model that can deal with the varying accuracy of location measurements. In line with other research in this area (such as [14]), TRIPZOOM uses a smart strategy to record trips in detail but applies less detailed sensing when people are in buildings, or on frequently used routes.

To implement the trip detection in a battery-efficient way, the application listens to 'significant' location changes using Wi-Fi (preferred) or GSM location updates and only enables the battery-hungry GPS if it has reasons to assume that the user has left the (static) location. Attempts to acquire a GPS fix are kept short – if there is no fix within that time, the GPS is turned off and will be re-enabled only after some time. By varying those time intervals, a trade-off is made between consuming battery power and attempting to record the trip as detailed as possible. We refer to [19] for details on this sampling strategy. Our initial tests within a limited user community have shown that battery life is 20 hours on average, with quite some variations related to differences in coverage (GSM, GPS, etc.) and mobile phone use.

The mobile application submits all location recordings to the TRIPZOOM server. All recorded trips are displayed on the mobile application to increase the awareness for personal mobility behavior. Specifically, regular trips, personal places and the mobility footprint of the user are visualized. The latter includes an estimate of the mobility impact in terms of costs, total and lost time, and CO_2 emissions.

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B. Server

On the back-end, the goal is to further enhance the data and to apply smoothing and outlier detection to the location data and to improve trip timings. To gather information on overall modality use and reward calculation, trips need to be stitched and split such that each segment is made of a single modality only. To facilitate modality detection, each route is mapped onto the underlying infrastructure network. Our algorithms estimate the modalities of each trip based on the location measurements as well as derived parameters such as the speed pattern, infrastructure usage, and origin and destination of the trip. The latter are automatically linked to places, to reveal the trip purpose, such as commuting between home and work, and improve the accuracy of modality recognition. Personal places frequently visited by the user in the past, like home or office, are recognized but can be adjusted by the user. Common places, like train station or theater, are mapped to crowd-sourced places as defined, e.g., in FOURSQUARE.

Trip modality recognition applies rules to all gathered information and calculates modality likelihoods. For example, a trip going from one airport to another with an average speed above 150km/h will likely have been made by plane. Users travelling on roads closed for car traffic are likely to walk or cycle depending on their speed pattern, etc. Still, it is important to allow users to manually adapt the recognized modality, in case of any error. The current system has an accuracy of about 77%, which already saves considerable effort compared to manually labeling all trips and is similar to other state-of-the-art approaches [20]. Its algorithm works better on ‘walking’, ‘cycling’, ‘car’, ‘plane’, and ‘train’ than on other modalities including ‘bus’ and ‘tram’. An improved approach for better recognizing those modalities is currently in the design phase.

VI. STATUS AND OUTLOOK

SUNSET is an ongoing project. After the identification of the stakeholders, the creation of usage scenarios and requirements analysis [21], the overall system has been designed and the architecture defined as described in the previous section. Several parts of it have already been implemented, connections to external infrastructure and sensor data have been established, and the underlying social network functionality has been provided. Additionally, functional prototypes of the mobile application (for iPhone and Android) are available and a basic web portal is running for evaluation purposes.

The next step after the finalization of the core system development is the start of living labs in three European cities (Enschede, NL, Gothenburg, SE, and Leeds, UK). In cooperation with city councils and public transport data providers, this serves as a test setting and evaluation platform [22] for the defined scenarios, algorithms such as modality and pattern detection, and the power of incentives. To maximize the overall outcome, each living lab will focus on different target groups and follow different evaluation goals [23]. The living labs will be started in a sequence to allow the transfer of the acquired knowledge and experiences from one to the next. Finally, we plan to assess the transferability of the system and living lab results to other cities and environments.

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