Smart Mobility and Sensing: Case Studies Based on a Bike Information Gathering Architecture

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Abstract. Mapping services and travel planner applications are experiencing a great success in supporting people while they plan a route or while they move across the city, playing a key role in the smart mobility scenario. Nevertheless, they are based on the same algorithms, on the same elements (in terms of time, distance, means of transports, etc.), providing a limited set of personalization. To fill this gap, we propose PUMA, a Personal Urban Mobility Assistant that aims to let the user add different factors of personalization, such as sustainability, street and personal safety, wellness and health, etc. In this paper we focus on the use of smart bikes (equipped with specific sensors) as means of transports and as a mean to collect data about the urban environment. We describe a cloud based architecture, personas and travel scenario to prove the feasibility of our approach.

Keywords: Smart mobility · Cloud based architecture
Crowdsensing · Crowdsourcing · Personal travel planner

1 Introduction

Smart mobility is playing a strategic role in our daily life in the urban scenario, taking into account that most people live in cities [1,2]. Thanks to the wide diffusion of mobile devices, several services and applications based on the geographical position of users are now available [4], which support citizens while they move across the urban environment [3]. In this context, personalization can be a key factor, enabling independence of citizens, despite some specific conditions (i.e. disabilities) [5] or means of transport [6]. Existing mapping services (e.g. Google Maps) and travel planners (e.g. OpenTripPlanner, Graphhopper) provide multimodal paths computed by the same algorithms, on the basis of the same elements: time, distance, and a limited set of means of transports (e.g. cars, public buses and metros, feet). However, it is not possible to add different factors of personalization, in terms of sustainability, street and personal safety, wellness and health, mood and satisfaction, accessibility. In this context, our idea is to

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design a system which acts as a Personal Urban Mobility Assistant (PUMA), supporting citizens in:

- collecting different information about the urban environment (by means of crowdsourcing and crowdsensing activities) in terms of: pollution, traffic, safety, health and fitness, etc.;
- exploiting gathered data, proving multimodal and multipreference paths in the urban environment.

In order to provide multimodal and multipreference paths in urban environments, a detailed mapping of all the elements that affect these factors (e.g., data about pollution, urban barriers and facilities, street lights, data about car accidents, data about crimes, etc.) is needed. Moreover, given out this information, it is necessary a system that lets each user customize and modulate the route computation on the basis of his/her own needs, instead of using the same algorithm for all. As regards the mapping, our approach is based on an open and participatory sensing and mapping system, with low cost sensors, which exploit users' devices too, in a common and shared data repository. We would take advantages by the potentialities of cloud architecture to create a modular open and crowdsourced system. In our work, we also tackled the following challenges:

- To introduce an innovative users' approach towards mobility choices that matches all impact factors for transportation, driving different transportation services, from single to shared, going next to the common existing booking systems, offering a social environment to share experiences and information on sustainable mobility and participate to challenges, info on traffic, lane condition and pollution [10], with the aim of supporting and improving eco-driving and sustainable behaviours [11].
- To develop a smart urban approach to mobility based upon way of booking transport systems that also take into account the carbon footprint [12].
- Integration of sustainable fleets with public transportation (i.e. buses and train) with the possibility to buy tickets by smart payment systems too.
- Data storage and data management (integration from different data sources: from public transportation and route conditions to air pollution obtained by sensors installed on bicycles or other vehicles [13], integration with traffic info).

In this paper, we focus on a specific means of transports: bikes [14]. Bikes can be equipped with different kinds of sensors and can be connected each other, so as to create a specific vehicular network, integrated with the urban infrastructure [7,8] and networks [9] thanks to a cloud architecture. The paper describes the system architecture and details personas and related scenarios, showing how it can be exploited by different users, with different needs and preferences, applying an *altruistic IoT* approach [15].

The remainder of the paper is structured as follows. Section 2 describes the system architecture. Section 3 defines some personas and Sect. 4 presents some use scenarios. Finally, Sect. 5 concludes the paper highlighting some final remarks and future work.

2 Cloud Architecture

In this section, we introduce our system architecture, specifically thought for bicycle vehicles, named BIGA (Bike Information Gathering Architecture), shown in Fig. 1. Our previous work [6] focused mainly on the adoption and implementation of a specific software engineering model that envisioned every component of a mobility application as a service; the reference model was based on microservices, therefore the SMAll architecture was tailored at proposing the definition of an open and standard interface for service access. Instead, BIGA architecture describes at high level the physical and software architecture that might be put in place to provide smart bicycle services. This means that BIGA might be adopted to host and provide the implementation proposed in the SMAll project. Bikes are equipped with sensing devices capable of gathering different kinds of information (data) not only from the environment (e.g., air pollution [16]), but also from the bike itself (e.g., traveled kilometers via odometer). Once (periodically) collected, such information are sent to an entity devoted either to provide connectivity or forwarding data to the cloud via Internet; this entity might be an infrastructure located along the road, such as for example a roadside unit (RSU), or a specific gateway. Cloud infrastructure is where data are processed, stored and made available for being consumed by multiple users.

The idea is to allow users, who are interested in gathering information, to personalize a plan for a given path, depending on their daily habits or needs. The cloud hosts the software that provides path customization and other useful services, but targeted for different uses, as described in the next section. This implies that different applications might require different ways of data collection. Therefore, multiple users can source information by accessing, for example, a web application in order to properly plan in advance their path, or use a mobile application on the smartphone not only for a priori decision, but for real time consultation as well. This means that data can be consumed prior and/or during the journey. At the end of the journey, users can decide to share their experience, i.e., share "collected information" along the path; this would allow to enrich databases with new information, thus resulting in improved bikers experience that can benefit of feedbacks coming from the community. Therefore, with our approach, users are both consumer and producer, so that data are both gathered and disseminated from/in the community.

The vision is that the Municipal District of Bologna (MDB) might act as service provider, i.e., providing to citizenship such "smart bicycles sharing" system. Smart bicycles would be equipped with devices targeted for the different applications (e.g., air pollution monitoring, fitness monitoring, personal safety and carbon footprint). MDB would then rent cloud resources at an infrastructure provider, whose goal would be to provide computational, network and storage resources to have service in place, besides the mobile and web application needed to interact with the service by remote users. Making the cloud hosting the applications, and making these applications available to customers, allow our "Bike as a Service" to fall under the hat of Software as a Service (SaaS). Indeed, cloud approach adoption brings several benefits:

- MDB has no need to install and run applications on their own computers, resulting in less expense in terms of buying new hardware, infrastructure provisioning and consequent maintenance.
- Other emergent paradigms might be put in place on need: Network Function Virtualization (NFV) and Software Defined Networking (SDN) might be adopted in synergy with cloud in order to provide flexible, programmable and cost effective solutions [17]. For example, software applications might run on a Virtual Machines (VMs) interconnected by a virtual network [18]; NFV would help in delivering services as virtual functions, while SDN would help in flexibly managing the (virtual) network [19].
- Cloud approach also calls for service on-demand model, that is, virtual functions could be instantiated, removed or migrated across the network without the need of deploying new hardware.

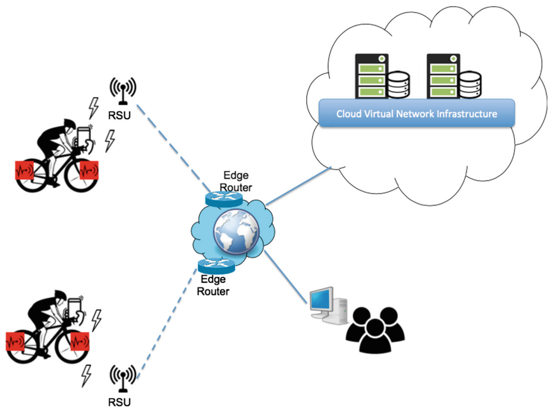

Fig. 1. System architecture

3 Personas

In this Section, we present three personas designed with the aim of defining scenarios exploiting different characteristics of our system.

3.1 Wei

Wei is a Chinese-American visiting Scholar, working to a joint research in Bologna for three months. His research interests are related to climate change and he is very committed in reducing his individual carbon footprint. These days in Bologna are mainly devoted to work and complete all the scheduled research tasks and experiments. In his free time, he likes to go around the city centre and explore the old town of Bologna (Fig. 2).

Wei works at the University of California, San Diego since 2007. He is in Bologna now for a joint research on climate change in the Department of Biological, Geological and Environmental Sciences of the Bologna University. Wei's family is based in S. Diego, where his wife Xiu Ying and his two children (Sean and May) live. They keep in touch with a daily call and Wei sends them a lot of pictures taken wandering around the city while he rides his bike. While in Bologna, Wei lives in the University guest quarters (Residenza di San Giovanni in Monte) located in a prominent monumental complex belonging to the University of Bologna, in the old town centre of Bologna. Wei uses a good trekking bike, loaned by a colleague from the Department for his stay in Bologna. He sporadically uses bus and other public means to reach destination that are too far from the city centre to be reached by bicycle. This responds both to Wei commitment to use sustainable transport and to his travel needs.

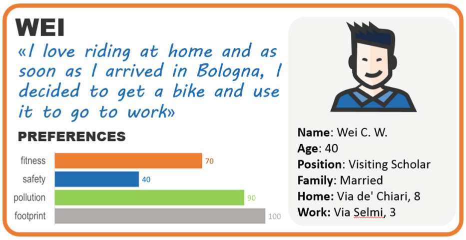

Fig. 2. Wei

3.2 Sven

Sven is a Swedish Erasmus student, living in Bologna for 6 months to complete his master thesis. He is vegan and he is obsessed with fitness. Stay in very good shape, eat vegan and whole food, have a generally healthy life style are very important goals to Sven. During his stay in Bologna, Sven goes to the Department to work to his thesis, to the gym to do his workout, without forgetting to go around with friends, having fun and enjoying the city life as all students do.

He is studying Film Directing at the Faculty of Fine, Applied and Performing Arts at the University of Gothenburg and he is completing his thesis on the Kill Bill movie series by Quentin Tarantino, working in the Department of Arts of the Bologna University. Sven is single. His family of origin lives in Hästevik, a small town near Gothenburg. They keep in touch on a weekly basis with a conference call. While in Bologna, Sven lives in a shared apartment in a neighbourhood outside the city centre. He decided for this location to share the room with his friend Hugo, who is taking his master degree in Economics and Finance in Bologna. The apartment is quite near to the Business and Economics School, where Hugo studies, but pretty far (about 4 km) from the Arts Department. Sven bought a cheap used mountain bike from another Erasmus student leaving Bologna few days after his arrival. He uses a mix of bike and bus to move around the city, depending from weather, time of the day, distance of the destination, but the bicycle is the most used mean to go to the Department and to the Gym on a daily basis because it represents an opportunity to do more workout and also to save money (Fig. 3).

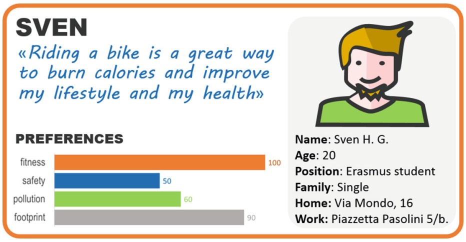

Fig. 3. Sven

3.3 Elena

Elena works full time at the University of Bologna. She was born in Bologna and she grow up in its city centre. Since her husband works in a nearby city, she is in charge of managing their son Tommaso (Tommy) and travel with him to and from school, or to and from her parents' house. While Elena prefers to use the car to reach points of interest outside the centre, when she goes downtown (to work, to Tommy's school and to her parents' house), she prefers to leave the car at home. Elena likes to ride the bike, but she is very worried for Tommy, by the safeness of the travel, weather issues and pollution that can be dangerous, especially during the winter.

Elena works for the University of Bologna since 2008. She works in the International Desk, providing information to students wishing to enroll at the University. She works since 8.30 AM to 4.30 PM for 5 days a week, having a fast lunch in the office nearby. Elena is married with Alberto since 2010 and they have a son, who is 4 years old. Tommy goes to a primary school (Betti Giaccaglia Plesso 2) located in the Montagnola Park, immediately near the Bologna Station. Elena got the option to enroll Tommy in this school because her father and mother live nearby and they are used to pick up Tommy from school every day at 4 PM. Tommy waits for Elena in grandparents' house, located in via Mascarella, for about an hour, to come back home with her. Elena lives in Bolognina, a neighbourhood outside the city centre, quite near to the train station. His husband, Alberto, works in Cesena and this location was chosen mainly to meet his need to easily reach the station. The place is not far from Tommy's School (about 1 km) and from Elena workplace (about 2 km), hence Elena uses a new red city bike, fully equipped with lights and reflectors, to enhance safeness of the travel, and with a baby seat on the back (Fig. 4).

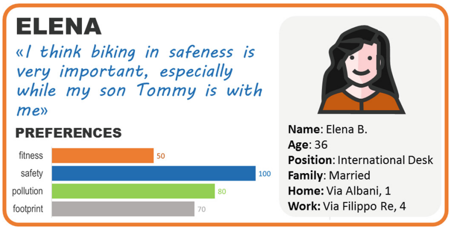

Fig. 4. Elena

4 Travel Scenarios

Travel scenarios related to the personas introduced in the previous section are described in the following subsections.

4.1 Wei

Wei is going to the weekly meeting of the research team, to reschedule some late experiments. It's a foggy day, but despite cold and humid, Wei is happy to take the bike. The meeting will be at 9.00 AM, Wei is leaving the University guest quarters early, so as to have a sweet breakfast in a bar near the Department without being in a hurry. Having more time than what is strictly required to reach his destination, he decided to enjoy the ride and cross the city mainly passing through restricted traffic zones.

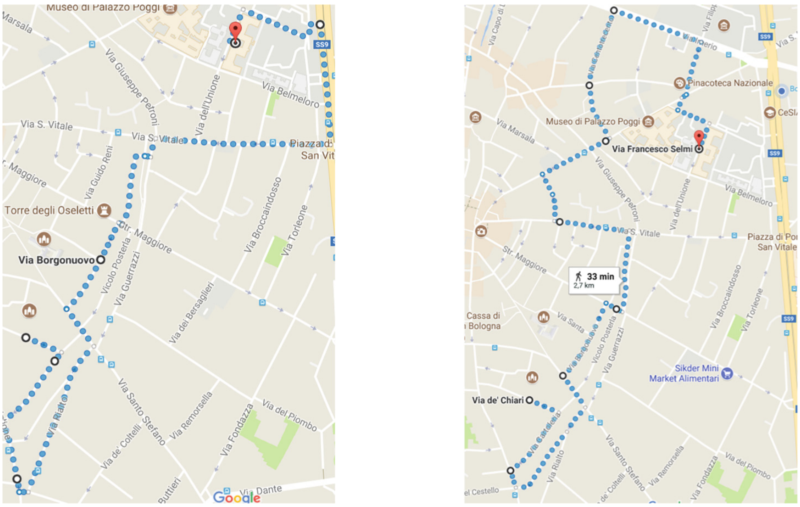

Fig. 5. Wei's routes

In Fig. 5, there are two different paths between Wei's starting point (Via de Chiari) and destination (Via Selmi). On the left side, there is the default and shortest path proposed for bikes by GraphHopper. On the right side, there is the personalized one based on the user's preferences, computed by our PUMA. This latter avoids one of the most congested and polluted roads of Bologna.

4.2 Sven

This morning Sven is going the Cineteca di Bologna to study some sources and will reach at noon his master thesis supervisor at the Department. The weather is not perfect, it is partially cloudy, but Sven prefers to use the bike because he will not have enough time for the Gym. So Sven prefers a longer path so as to do a good workout. Our PUMA proposes a longer path, a path through different green areas and some slopes, as shown in Fig. 6.

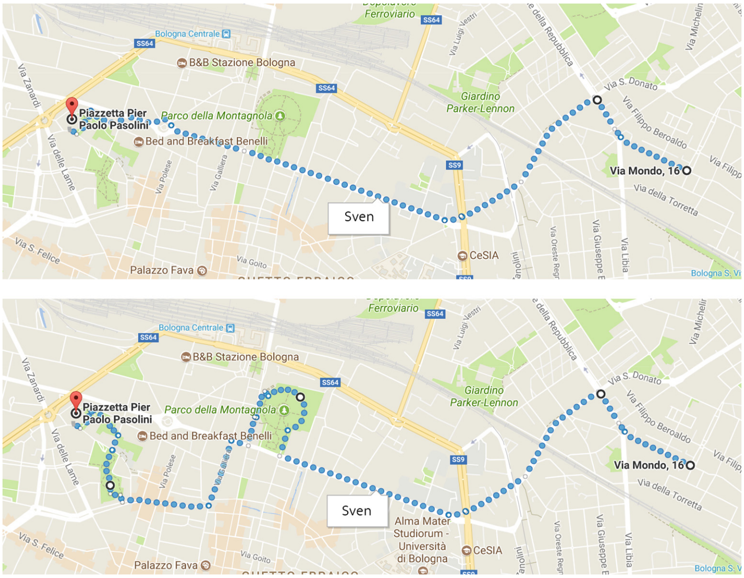

Fig. 6. Sven's routes

4.3 Elena

Elena is going to work, she will leave Tommy at the school on her way. The weather is very good, 25 °C, a perfect spring day with a perfect temperature. She is leaving in at 7.45 AM, just in time to stop at the School, say bye to Tommy and go to work in schedule without being in a hurry. She decides to go safe using the available bicycle lanes and to select a route through parks and green areas to enjoy the spring weather and avoid a large exposure to pollutant. Our system proposes a path that does not cover Via Irnerio (as shown in Fig. 7), a route not safe for cyclist because of the traffic, that includes cars and buses, and not clean, due to the pollution produced by these means of transport.

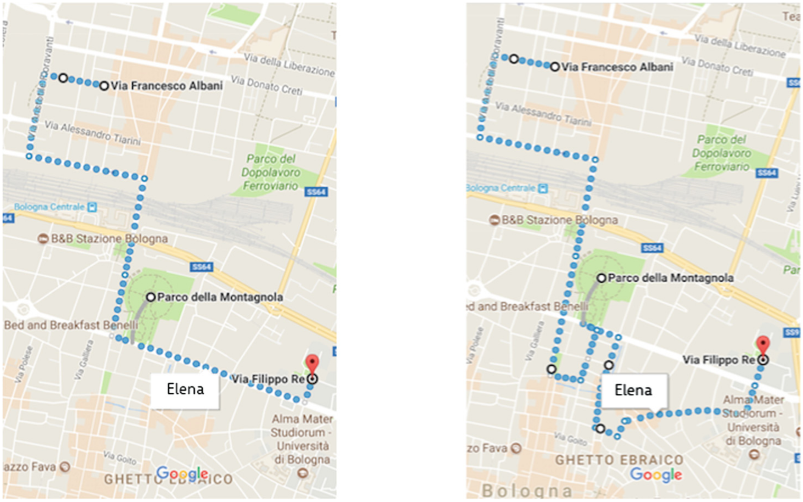

Fig. 7. Elena's routes

5 Conclusions

This paper presents a Personal Urban Mobility Assistant (PUMA) system, based on the idea of letting citizens and public administrations gathering and exploiting integrated information about the urban environment, by using web applications and mobile devices. Users are at the same time producers and consumers of data and services, thanks to a cloud architecture approach, providing typical SaaS benefits. The paper focuses on a specific mean of transport: bikes. It describes three different personas and related scenarios, with the aim of illustrating how our system can support smart and sustainable mobility in a urban scenario, thanks to crowdsourcing and crowdsensing activities.

References

1. Mirri, S., Prandi, C., Salomoni, P., Callegati, F., Melis, A., Prandini, M.: A service-oriented approach to crowdsensing for accessible smart mobility scenarios. Mob. Inf. Syst. **2016** (2016)
2. Melis, A., Mirri, S., Prandi, C., Prandini, M., Salomoni, P., Callegati, F.: Integrating personalized and accessible itineraries in MaaS ecosystems through microservices. Mob. Netw. Appl. 1–10 (2017)
3. Chourabi, H., Nam, T., Walker, S., Gil-Garcia, J.R., Mellouli, S., Nahon, K., Scholl, H.J.: Understanding smart cities: an integrative framework. In: 2012 45th Hawaii International Conference on System Science (HICSS), pp. 2289–2297. IEEE, January 2012
4. Dusi, N., Ferretti, I., Furini, M.: PlayTheCityRE: a visual storytelling system that transforms recorded film memories into visual history. In: 2016 IEEE Symposium on Computers and Communication (ISCC), pp. 85–90. IEEE, June 2016

5. Mirri, S., Prandi, C., Salomoni, P.: Personalizing pedestrian accessible way-finding with mPASS. In: 2016 13th IEEE Annual Consumer Communications & Networking Conference (CCNC), pp. 1119–1124. IEEE (2016)
6. Mirri, S., Prandini, M., Salomoni, P., Delnevo, G., Callegati, F., Melis, A.: I want to ride my bicycle: a microservice-based use case for a MaaS architecture. In: 2017 IEEE Symposium on Computers and Communication (ISCC). IEEE (2017)
7. Marfia, G., Pau, G., Giordano, E., De Sena, E., Gerla, M.: Vanet: on mobility scenarios and urban infrastructure. A case study. In: 2007 Mobile Networking for Vehicular Environments, pp. 31–36. IEEE (2007)
8. Roccetti, M., Gerla, M., Palazzi, C.E., Ferretti, S., Pau, G.: First responders' crystal ball: how to scry the emergency from a remote vehicle. In: IEEE International Performance, Computing, and Communications Conference, IPCCC 2007, pp. 556–561. IEEE, April 2007
9. Ghini, V., Salomoni, P., Pau, G.: Always-best-served music distribution for nomadic users over heterogeneous networks. IEEE Commun. Mag. **43**(5), 69–74 (2005)
10. Tse, R., Zhang, L.F., Lei, P., Pau, G.: Social network based crowd sensing for intelligent transportation and climate applications. Mob. Netw. Appl. 1–7 (2017)
11. Di Lena, P., Mirri, S., Prandi, C., Salomoni, P., Delnevo, G.: In-vehicle human machine interface: an approach to enhance eco-driving behaviors. In: Proceedings of 2017 ACM Workshop on Interacting with Smart Objects, pp. 7–12. ACM (2017)
12. Bigazzi, A.Y., Figliozzi, M.A.: Roadway determinants of bicyclist exposure to volatile organic compounds and carbon monoxide. Transp. Res. Part D **41**, 13–23 (2015)
13. Alvear, O., Zamora, W., Calafate, C.T., Cano, J.C., Manzoni, P.: EcoSensor: monitoring environmental pollution using mobile sensors. In: 2016 IEEE 17th International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM), pp. 1–6. IEEE, June 2016
14. Lerner, W., Van Audenhove, F.J.: The future of urban mobility: towards networked, multimodal cities in 2050. Publ. Transp. Int.-Engl. Ed. **61**(2), 14 (2012)
15. Mirri, S., Prandi, C., Salomoni, P., Monti, L.: Social location awareness: a prototype of altruistic IoT. In: 2016 8th IFIP International Conference on New Technologies, Mobility and Security (NTMS), pp. 1–5. IEEE, November 2016
16. Tse, R., Pau, G.: Enabling street-level pollution and exposure measures: a human-centric approach. In: Proceedings of 6th ACM International Workshop on Pervasive Wireless Healthcare, pp. 1–4. ACM (2016)
17. Callegati, F., Cerroni, W., Contoli, C., Santandrea, G.: SDN controller design for dynamic chaining of virtual network functions. In: 2015 4th European Workshop on Software Defined Networks (EWSDN), pp. 25–30. IEEE (2015)
18. Callegati, F., Cerroni, W., Contoli, C., Santandrea, G.: Performance of multi-tenant virtual networks in OpenStack-based cloud infrastructures. In: 2014 Globecom Workshops (GC Wkshps), pp. 81–85. IEEE (2014)
19. Callegati, F., Cerroni, W., Contoli, C., Santandrea, G.: Implementing dynamic chaining of virtual network functions in OpenStack platform. In: 2015 17th International Conference on Transparent Optical Networks (ICTON), pp. 1–4. IEEE (2015)