Carpooling in Urban Areas: A Real-Time Service Case-Study

Matteo Mallus[1,2(✉)], Giuseppe Colistra[1,2], Luigi Atzori[1], and Maurizio Murroni[1]

[1] DIEE, University of Cagliari, Cagliari, Italy
{matteo.mallus,giuseppe.colistra,l.atzori,murroni}@diee.unica.it
[2] GreenShare SRL, Cagliari, Italy

Abstract. The realization of the smart city paradigm relies on the implementation of various innovative systems. Among the sectors of interest for a smart city, the sustainable transport is a key service where carpooling solutions are gaining more and more popularity in the last years. The most widespread use of the carpooling relies on a bakeca approach (i.e., the trips are planned well in advance), which is however not suitable in urban areas where the users are looking for an immediate companion. In this paper, we focus on the challenge of a real-time carpooling service and provide the following contribution: the Clacsoon platform is described, which is intended to make easy for the clacsooners to find the companion of the trip; an emulation system is implemented, which is used to generate increasing numbers of users that interact with the Clacsoon platform to evaluate the performance; based on the emulator, extensive trials are implemented to analyse the quality of experience provided to the users varying the characteristics of the population; from the results we extract important information about the challenges to be addressed for successful deployments of a real-time carpooling service.

Keywords: Real-time carpooling · Smart city · Internet of Things · Smart transport

1 Introduction

Sustainable transport is a key service of smartcities. It is expected to be friendly in the sense of social, environmental and climate impacts and the ability to, in the global scope, supply the source energy indefinitely. For the evaluation of the impact it has to be taken into account the particular vehicles used for the transport, the source of energy and the infrastructure used to implement the transport (Mihyeon Jeon and Amekudzi 2005). For sure public transport

This work has been partially funded by GreenShare SRL during the development of CLACSOON project (www.clacsoon.com) and Carpooling for Green Communities (COOG-IT) project (P.O.R. Sardegna F.S.E. Operational Programme of the Autonomous Region of Sardinia).

B. Mandler et al. (Eds.) IoT 360° 2015, Part I, LNICST 169, pp. 157–166, 2016.
DOI: 10.1007/978-3-319-47063-4_14

services are those that have received a great attention in this respect, with several solutions that have been proposed and deployed according to the specific city configurations (city buses, trolleybuses, trams (or light rail) and passenger trains, rapid transit (metro/subways/undergrounds etc.) and ferries).

An alternative solution that is receiving a lot of attention in the last years is carpooling. It is the sharing of the private car journeys so that more than one person travels in a car. By having more people using one vehicle, carpooling reduces each person's travel costs such as fuel costs, tolls, and the stress of driving. Carpooling is seen as a more environmentally friendly and sustainable way to travel than the classical use of private cars. Indeed, sharing journeys reduces carbon emissions, traffic congestion on the roads, and the need for parking spaces. Authorities often encourage carpooling, as it is the case of the highways lanes that in the USA are reserved to cars with more than one person inside. Other than the above mentioned advantages, carpooling service presents the important features of giving people the possibility to interact during the setting of the sharing ride but especially during the ride, which represent a particular moment for the commuters that are typically keen on sharing thought and experience as well (Dakroub et al. 2013).

It is a matter of fact that this service is having a bootstrap thanks to the advancements in the ICT sector and wide diffusion of Internet connection that allow for the deployment of powerful tools for both the carpoolers to meet potential companions and reach an agreement on the shared trips (Blablacar 2015; CUTR 2015). These tools also help in evaluating the trustworthiness of the companions and the use of the social networks to share feedback about the members. However, the most widespread use of the carpooling solutions rely on a bakeca approach, i.e. the carpoolers post the request and the offers for a future transportation need. They have then the time to think about the posts and find an agreement on the remunerations. Indeed, a real-time approach has some difficulties in finding real exploitations. In this case, the users are looking for an immediate companion because the need for mobility is now (or up to 10 min). This scenario is typical of urban or suburban mobility where the flexibility is a key requirement as so the mobility needs cannot be scheduled one day before.

In this paper, we focus on the challenge of a real-time carpooling service and provide the following contribution: the Clacsoon platform (CLACSOON 2015) is described, which is intended to make easy for the clacsooners to find the companion of the trip; an emulation system is implemented, which is used to generate increasing numbers of users that interact with the Clacsoon platform to evaluate the performance; based on the emulator, extensive trials are implemented to analyse the quality of experience provided to the users varying the characteristics of the population; from the results we extract important information about the challenges to be addressed for successful deployments of a real-time carpooling service. The paper is organized as follows. Section 2 presents past works of relevance. Section 3 describes the implemented platform. Section 4 presents the experimental results. Conclusions are drawn in last section.

2 Past Works

The concept of Smart City has been commonly defined as the use of Information and Communication Technology (ICT) to sense, analyse and integrate the key information of core systems in running cities. In a more social way Smart City is an innovative city that uses ICTs and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects (ITU 2010). On the technical side, telecommunication infrastructures play a vital role in enhancing the connectivity and sustainability of the cities and, more specifically, Machine to Machine (M2M) communications play an important role within ICT for enabling Smart Cities. M2M communications for Smart Cities refers to the exchange of information between autonomous devices in control and monitoring applications without human intervention (Wu et al. 2011). The decline in communication fees, altogether with the massive adoption of real-time access of information is expanding the consideration of new services and applications and solutions based on this type of communication. Internet of Things (IoT) (Atzori et al. 2010) services are candidate to enable M2M communications and in general to support the development of smart applications, such as smart transportation (Nitti et al. 2014), smart buildings (Cherchi et al. 2014), etc. Carpooling on the strength of ICT has been a widely accepted concept to implement better transportation systems in Smart Cities. However in reality, most of current carpooling systems or applications are not functioned well as the expected. Carpooling system aims at raising vehicle occupancy based on a user collaborative environment motivated on a credits mechanism that can be converted into parking licenses in facilities of big cities. The carpooling happens whenever at least two people ride the same car. Each person would have made the trip independently if the carpool had not been there. Driver and passengers know beforehand the trips that they will be sharing the ride. This idea is not new and several initiatives have been tried in the past in the field of business, but also like a research topic (Agatz et al. 2012; Arnould et al. 2011; Blablacar 2015; CUTR 2015; Teal 1987). Most of these systems allow convenient trip arrangements over the internet, support trust building between registered users, and they implement billing systems to charge passengers and compensate drivers. The main technical drawback of existing ride sharing services is that do not allow truly ad-hoc real-time trip arrangements. Today's mobile computing with current advances on geographic location systems (e.g.,GPS, WiFi) (Araniti et al. 2010), mobile communications (e.g., 4-5 G) (Araniti et al. 2012) and new mobile devices (e.g., smart-phones, tablet) and navigations platforms overcame this limitation and enable for the first time truly ad-hoc real-time ride sharing services.

3 Reference System Architecture

In this work we consider a urban scenario where the aim is to offer a real-time carpooling service. The main functional requirements to develop this service can be described as follows:

- *Accounting*: to allow the user to access the service. Each user has a profile various information is stored, such as name, age, type of car, received feedback, etc.
- *Request and offer insertion*: through this feature each user can insert an offer or request of a ride. Each ride is identified by a start point, arrival point and a researc radius representing the maxim deviation from the scheduled trip.
- *Automatic matching*: the server calculates if there is a matching between an offer and a request of a ride. Matching is evaluated in real-time considering: the starting and arrival points of passenger, passenger's research radius, route travelled by the driver and driver's research radius.
- *Matching notification*: if there is a matching the system notifies the user. This notification contains the pick-up point (where the ride can start), the drop-off point (where the ride can finish) and the expected driver arrival time. Each user can accept o refuse the notification.

The system has to be used by users in mobility, so the access of the system has to be guaranteed by mobile devices. Accordingly, the design of the system architecture considers this facility and the front-end layer is projected for a mobile devices. As to the back-end, the system is developed completely in the cloud to offer good reliability for a lot of connections and to offer a better flexibility in terms of resources scaling. In the implementation of this case study the technology chosen is GoogleAppEngine and its tools for cloud solution.

As already mentioned, the system follows the paradigm mobile-cloud. Figure 1 shows the major components:

- *Mobile client* allows the user to access the carpooling service in mobility. Its sensors (e.g. GPS) are used to simplify the access of the service and to enhance the user experience. For all communications toward the server JSON format is used.
- *Cloud application server* is the core of the system. It enables the access of users, processes all requests and offers of rides and calculates the matching between requests and offers.
- *MySQL cloud database* has the task to store all data useful for the service: user profile, ride offers, ride requests, etc.
- *Facebook APIs* are used to simplify the process of registration by offering a quick and easy service to access on the system. Using the facebook social graph the aim is to increase the social participation of users.
- *Direction and location services* are used to evaluate the route between the two points (start point and arrival point) chosen by the user for its ride. These services are used also for the geocoding of address, that is the conversion of text in coordinates.
- *Push notification services* are used to enable the push notification toward smartphones. This feature is a milestone to obtain the real-time requirement.

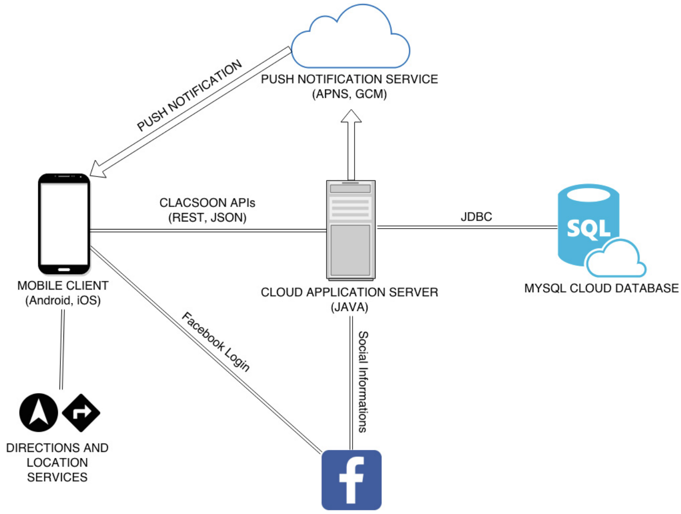

Fig. 1. Functional blocks description

4 Cagliari Case Study

This section describes the case study simulated. A large scale deployment of the system, to a real experiments, it's not easy because we need a lot of volunteers. Therefore the first experiment is an emulation of the carpooling service in a real area using simulated users. The place selected for the experiment is a real city: the metropolitan area of Cagliari. It is an Italian municipality. It has nearly 150.000 inhabitants, while its metropolitan area (including Cagliari and 15 other municipalities) has more than 422,000 inhabitants (Wikipedia 2015). Using a real area we can emulate the service in real urban conditions, considering real roads in the city and real paths between two points (e.g. pedestrian zone, one-way roads, limited traffic zones). A real-time carpooling service in Cagliari is simulated to evaluate two KPIs: the number of ride concluded and the waiting time to find a ride. The simulation achievement is to study the service performance in a typical urban scenario, analysing the contribution of spatial and time distributions.

4.1 Simulation Setup

At the first the area of interest is delimited by a box centered in point (39.23,9.14), which has a surface (A) of about 64 kmq, so the user can operate only inside this zone. Figure 2 shows the place selected for this case study, the area of interest is delimited by a black line.

The effectiveness of the carpooling service has been simulated considering the evaluation of two key performance indicators (KPIs): the first is the number of rides concluded and the second is the waiting time to find a ride (i.e., passenger

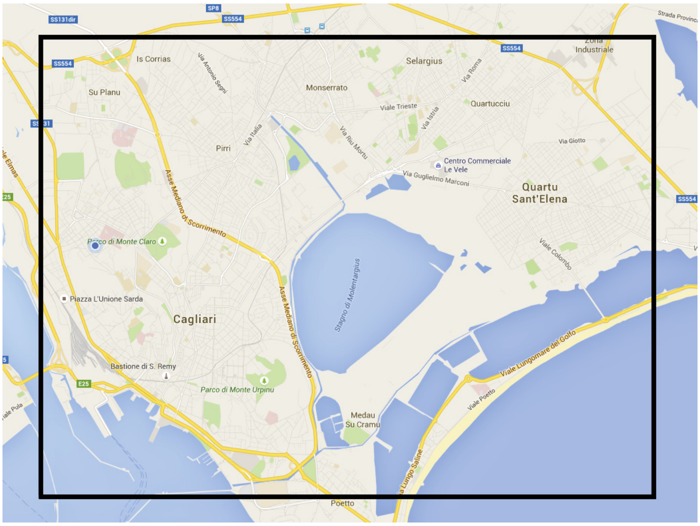

Fig. 2. The area for the case study

waiting time). Both these indicators are computed from the passenger perspective. A timeout (T) has been set, which is the limit within which a ride has to be found for the passenger before retiring her request (it has been set to 10 min in the experiments). During the experiments we have changed some parameters to evaluate the effects on the KPIs. The list of parameters that we have changed during the simulation is described in Table 1.

The emulator, according to the rate of ride creation, creates a request or an offers of ride between a starting point and arrival point. These two points are chosen randomly uniformly inside the area delimited during the setup. If the user is a driver (i.e. ride offer), the system calculates the route between the two points, moreover it evaluates the travel time, using Google services, to simulate the mobility pattern inside the route. The back-end receives all the offers and the requests to evaluate the matching according to the research radius of each user. The research radius of passenger (Rp) is 100 m and for driver (Rd) is 1000 m. If there is a matching, before the timeout, the system simulates the notification to appropriates users. In this first case study, if there is a matching the ride is considered agreed.

4.2 Simulation Results

To evaluate the performance in relation with the spatial distribution, the percentage of population who uses the service is changed. The number of users per kmq is changed to evaluate the dependence in relation of the service penetration among citizens. Instead to evaluate the dependence with the number of passengers and drivers, also the ratio between number of drivers (nd) and number of

Table 1. Values of parameters varied during experiment

System parameters		
Total users	N	from 600 to 2500
Overall area	A	64 kmq
Requests timeout	T	10 min
Users/kmq	Nk	from 9 to 39
Research radius of passengers	Rp	100 m
Research radius of drivers	Rd	1000 m
Percentage of drivers	nd	nd/np in the range from 0.25 to 4
Percentage of passengers	np	
Temporal rate of ride offers	Ld	Ld/Lp in the range from 0.2 to 5
Temporal rate of ride requests	Lp	

passengers (np) is changed. The performance, in relation with the time distribution of the service utilization, are evaluated varying the rate of ride offers and the rate of ride requests. The creation of ride events is modeled using an exponential distribution. To evaluate the dependence, during the simulation has been varied the ratio between the average ride inter-offer time (named Ld) and the average ride inter-request time (named Lp). Both distributions are exponential functions. Figures 3 and 4 show the KPIs analysed during this study. In each graph the KPIs are evaluated varying the parameters with the values indicated in Table 1.

Figure 3 shows the request success rate in the discussed case study. The first trend highlighted is that the success rate decreases if the population of user decreases. This trend is clear because if the spatial distribution of users is low, the probability to have a matching is small. Another important trend is that if there are more drivers, the passenger success rate is high. Also this trend is obvious, if there are more offers of service, the probability to satisfy a generic request is higher than a case with few offers. The last trend is the dependence of the temporal distribution. The success rate is plotted varying the ratio between the mean of temporal ride distribution. Analysing the figure, the trend of the success rate is concave. The maximum is near the centre, where the ratio is one, so the temporal distribution of requests and offers is the same. If the temporal distribution of requests and offers is the same, the system is balanced and the probability to find a matching is higher than an unbalanced system.

Figure 4 shows the passenger waiting time in the discussed case study. The first trend highlighted is the dependence between the waiting time and the temporal rate of requests and offers. In all cases simulated the waiting time increases if the ratio Ld/Lp increases, so the mean of temporal distribution of ride requests is smaller than ride offers. In this case the requests of passengers are distributed in an interval more tight than the drivers, so the probability to find for all requests a ride quickly is low. Instead if the situation is overturned, the probability to find a

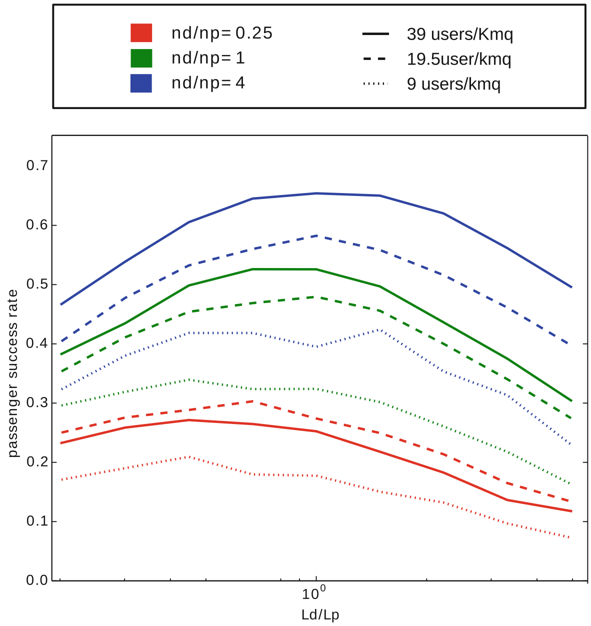

Fig. 3. Passenger success rate

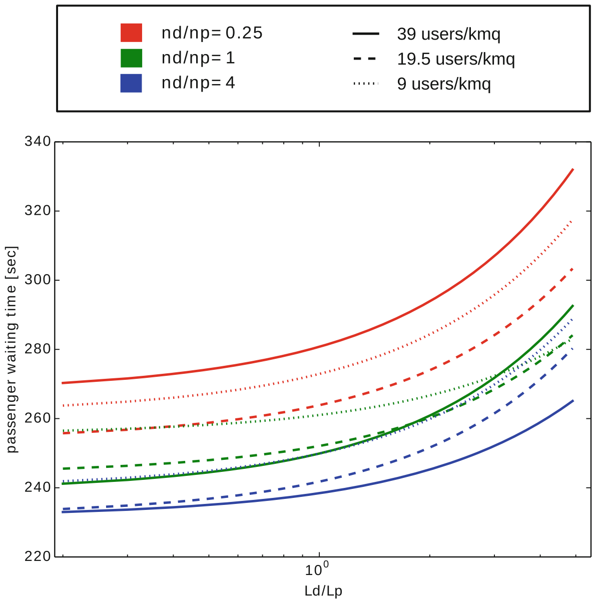

Fig. 4. Passenger waiting time

ride quickly is substantial so the average of waiting time decreases. Another trend very clear is the dependence of percentage of passengers. If the ratio nd/np is high (i.e. more drivers) the waiting time is low and vice versa. In the case with more drivers, there are more offers, so the probability to find a ride quickly is higher than the case where there are few drivers.

5 Conclusion and Future Works

In this work, a case study of urban real-time carpooling service has been studied. The results presented in this paper can be used to evaluate the requirements to build a urban carpooling with good performance. The city of Cagliari has been the real scenario to simulate the service. In this context has been simulated the presence of users who offer or require a ride between two point in the city.

Proposed case study is intended to evaluate the performance of service in relation with the spatial distribution of users, the population of drivers and passengers and the temporal distribution of ride offers and requests. The performance of the service has been evaluated considering two KPIs: rate of ride concluded and waiting time to find a travel companion. For both KPIs are identified the dependence between them and other important factors like: spatial distribution of users, percentage of drivers and passengers, temporal distribution of requests and offers.

Future works will be focused on the use of even more real scenario. During the design of the model can be identified the main start and end points in the uptown and the commercial areas. This model permits to simulate the main pattern of the urban travel between home and work. Furthermore, the proposed real-time carpooling service can be tested in real situation involving a community of volunteers to validate the simulation results.

References

Agatz, N., Erera, A., Savelsbergh, M., Wang, X.: Optimization for dynamic ride-sharing: a review. Eur. J. Oper. Res. **223**(2), 295–303 (2012)

Araniti, G., Sanctis, M., Spinella, S.C., Monti, M., Cianca, E., Molinaro, A., Iera, A., Ruggieri, M.: Hybrid system HAP-WiFi for incident area network. In: Sithamparanathan, K., Marchese, M., Ruggieri, M., Bisio, I. (eds.) PSATS 2010. LNICSSITE, vol. 43, pp. 436–450. Springer, Heidelberg (2010). doi:10.1007/978-3-642-13618-4_33

Araniti, G., Scordamaglia, V., Condoluci, M., Molinaro, A., Iera, A.: Efficient frequency domain packet scheduler for point-to-multipoint transmissions in LTE networks. In: 2012 IEEE International Conference on Communications (ICC), pp. 4405–4409. IEEE (2012)

Arnould, G., Khadraoui, D., Armendáriz, M., Burguillo, J.C., Peleteiro, A.: A transport based clearing system for dynamic carpooling business services. In: 2011 11th International Conference on ITS Telecommunications (ITST), IEEE, pp. 527–533. IEEE (2011)

Atzori, L., Iera, A., Morabito, G.: The internet of things: a survey. Comput. Netw. **54**(15), 2787–2805 (2010)

Blablacar, Blablacar ridesharing (2015). https://www.blablacar.it/. Accessed 30 July 2015

Cherchi, R., Colistra, G., Pilloni, V., Atzori, L.: Energy consumption management in Smart Homes: an M-Bus communication system. In: 2014 International Conference on Telecommunications and Multimedia (TEMU), IEEE, pp. 80–85. IEEE (2014)

CLACSOON, CLACSOON urban real-time carpooling (2015). https://www.clacsoon.com/. Accessed 30 July 2015

CUTR, Ridematching software – CUTR Center for Urban Transportation Research (2015). http://www.nctr.usf.edu/programs/clearinghouse/ridematching-software/. Accessed 30 July 2015

Dakroub, O., Boukhater, C.M., Lahoud, F., Awad, M., Artail, H.: An intelligent carpooling app. for a green social solution to traffic and parking congestions. In: 2013 16th International IEEE Conference on Intelligent Transportation Systems-(ITSC), IEEE, pp. 2401–2408. IEEE (2013)

ITU, Smart sustainable cities: An analysis of definitions. Focus Group of Telecommunication Standardization Sector of ITU (2010)

Mihyeon Jeon, C., Amekudzi, A.: Addressing sustainability in transportation systems: definitions, indicators, and metrics. J. Infrastruct. Syst. **11**(1), 31–50 (2005)

Nitti, M., Girau, R., Floris, A., Atzori, L.: On adding the social dimension to the internet of vehicles: friendship and middleware. In: 2014 IEEE International Black Sea Conference on Communications and Networking (BlackSeaCom), IEEE, pp. 134–138. IEEE (2014)

Teal, R.F.: Carpooling: who, how and why. Transp. Res. Part A Gen. **21**(3), 203–214 (1987)

Wikipedia, Cagliari – Wikipedia, The Free Encyclopedia (2015). https://en.wikipedia.org/w/index.php?title=Cagliari&oldid=671950070. Accessed 30 July 2015

Wu, G., Talwar, S., Johnsson, K., Himayat, N., Johnson, K.D.: M2m: from mobile to embedded internet. IEEE Commun. Mag. **49**(4), 36–43 (2011)