Social Drive: A Crowdsourcing-based Vehicular Social Networking System for Green Transportation

Xiping Hu[1], Victor C. M. Leung[1], Kevin Garmen Li[1], Edmond Kong[1], Haochen Zhang[1], Nambiar Shruti Surendrakumar[2], Peyman TalebiFard[1]

[1]Dept. of Electrical & Computer Engineering, The University of British Columbia, Vancouver, Canada V6T 1Z4

[2] Dept. of Computer Science, Birla Institute of Technology & Science-Pilani, Dubai

{xipingh, vleung}@ece.ubc.ca

ABSTRACT

This paper presents Social Drive, a novel crowdsourcing-based vehicular social networking (VSN) system for green transportation. Social Drive integrates the standard vehicular On-Board Diagnostics (OBD) module, leverages the advantages of cloud computing and popular social networks, and incorporates a novel rating mechanism about the fuel economy of drivers. Based on these, Social Drive provides a user-friendly mobile application on smartphones targeting drivers, which enables a seamless and economic solution that promote drivers' awareness of their driving behaviors regarding fuel economy of specific trips. Our practical experiments have demonstrated that Social Drive works efficiently with low battery consumption and low networking overhead on popular mobile devices.

Categories and Subject Descriptors

C.2.4 [**Computer Systems Organization**]: COMPUTER COMMUNICATION NETWORKS - Distributed Systems - Distributed applications.

General Terms

Design, Human Factors, Economics.

Keywords

Vehicular social networks, mobile application, database, cloud.

1. INTRODUCTION

Everyday, a large number of urban dwellers spend hours traveling along the same routes at about the same time on their commute to and from work. Their travel patterns are highly predicable and regular. Consequently, there is an opportunity to form recurring virtual mobile communication networks and social communities between these travelers or their vehicles in the form of vehicular social networks (VSNs) [1]. Unlike conventional mobile social networks, where the participants are humans who converse with one another using mobile phones, the participants of VSNs are heterogeneous, and include vehicles, devices onboard vehicles, as well as drivers, passengers, and pedestrians. Thus, three types of relationships are found in VSNs: (i) between human and human, (ii) between human and machine, and (iii) between machine and machine. Previous research has shown that knowledge from the social interactions between nodes can help to improve the performance of mobile systems [2-4]. Therefore, it is anticipated that VSN applications can be effectively used for many purposes. The three most common types of applications over VSNs are: (a) Safety improvements: applications that improve the safety of drivers, passengers and pedestrians by notifying them about any dangerous situations on the roads [5]; (b) Traffic management: applications that provide users with up-to-date traffic information and recommendations that enable them to make better decisions to reduce travel time, and hence improving traffic flow and driving efficiency; (c) Entertainment: applications that enable the streaming, downloading, or sharing of multimedia files over the VSN [6]. In this paper, we focus on the second type of VSN applications.

With the popular use of smart phones and other mobile devices, especially for social networking applications, people can easily interact and share information with each other anytime and anywhere. There is a remarkable trend to leverage mobile devices and applications to enable crowdsourcing in order to address a diversity of problems that involve real-time data collection and processing, and collaborations among a large number of participants in mobile environments to contribute their experience in an effective and economical manner [7]. Crowdsourcing not only potentially brings huge economic benefits, but also leads to revolutions in many aspects of our daily lives. Thus, a connection exists naturally between VSN and crowdsourcing, where VSN applications can be developed to address many crowdsourcing problems, while crowdsourcing could be an emerging strategy to improve the user experience and efficiency of VSN applications.

Currently, a number of crowdsourcing based mobile applications that target green transportation have been successfully applied to vehicular application scenarios, such as UbiGreen [8], Cyber-physical bike [9], GreenGPS [10], and HyDi [11]. However, most of them focus on the functionalities of the applications themselves, but not much has been considered about how to enable the users in vehicular environments to participant in such applications easily and widely; e.g., a friendly user interface (UI) is lacking in many of these applications, and most of them have not leveraged the advantages of popular social networks to support large groups of users. Moreover, a seamless and comprehensive solution that could support real-world deployment of VSN applications is also lacking. This paper fills the gaps identified above by proposing

DIVANet'13, November 3- 8, 2013, Barcelona, Spain.

Copyright 2013 ACM 978-1-4503-2358-1/13/11 ...$15.00.

http://dx.doi.org/10.1145/2512921.2512924

Social Drive, a crowdsourcing-based VSN system for green transportation. Our major contributions are summarized as follows:

- We present the design and practical implementation of Social Drive. Social Drive provides the first seamless solution that integrates vehicle onboard devices such as onboard diagnostic (OBD) port readers with commercial social networks such as Facebook. It provides a user friendly mobile application that provides drivers with feedback about their driving behaviors and shares users' trip information via widely used social networks, which can stimulate people to improve their driving habits for better fuel economy that contributes towards green transportation.
- We deploy and evaluate Social Drive through a set of real-world scenarios, which not only verify the feasibility of Social Drive, but also provide practical experience that inspire future research and development of mobile social networking applications for green transportation.

Here is an outline of the rest of this paper. In Section 2 we review the background and related techniques that we adopt to develop and deploy the Social Drive. Then, we present the overall system design and key components of the Social Drive system in Section 3. Section 4 introduces the practical implementation strategies of the Social Drive system. Practical evaluations of Social Drive are provided in Section 5. Related work is reviewed and compared with Social Drive in Section 6. Section 7 concludes this paper.

2. BACKGROUND

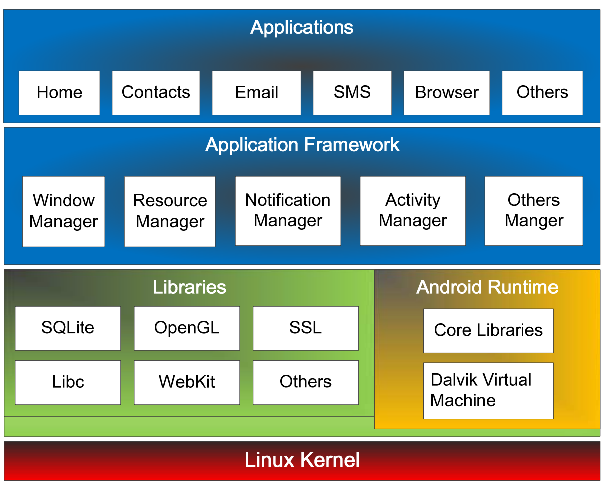

Figure 1. Android system architecture

The Android [12] operating system is a freely available open sourced software platform for mobile devices. As shown in Figure 1, the architecture of Android, supported by Java-based application programming interfaces (APIs), is designed to simplify the reuse of components, including Android's built-in applications for email, message, camera, browser, maps, and others. Android also includes a wide range of libraries, such as database (SQLite), graphics (OpenGL, SGL), location (GPS), networking (SSL), web (WebKit), and so on. Its Software Development Kit (SDK) includes plugins and support for Eclipse and other integrated development environments. Each Android application runs in its own process with its own instance of the Dalvik virtual machine that runs the Java byte codes and uses the Linux kernel for low-level functionality. Also, Android phones support some of the major wireless access protocols, such as GSM/EDGE, CDMA, EV-DO, WiFi, Bluetooth, and others. In addition, since open source is an intrinsic feature of Android, many researchers are also conducting their studies based on the Android system, e.g., some researchers are focusing on designing middleware in Android, so as to support the mobile social ecosystems [13]. Thus, considering the open sourced nature and friendly application development support, e.g., the sufficient SDK support for the real-time connection between the OBD devices onboard vehicles and mobile devices, the current version of Social Drive is developed based on the Android operating system.

Facebook [14] is a social networking service and website that was launched in 2004. It is widely used and studied by researchers interested in the functions and services of social networks, as it contains diverse usage patterns and technological capacities that bridge online and offline connections [15]. Also, it provides rich APIs for its mobile version, which means that application developers can create applications that add more functionality to the original mobile Facebook application. For instance, there are several new mobile Facebook applications that provide location-aware services by allowing users to update their geographic status, browse the current locations of their Facebook friends, and sort them by distance. In Social Drive, we make use of the APIs of Facebook to develop the web application of Social Drive, so as to enable users to share and comment on each other's trip information (i.e., achievement of fuel consumption) of Social Drive via Facebook.

Cloud computing is evolving as a key computing environment to enable the sharing of resources such as infrastructures, platforms, and value-added services/applications [16]. Cloud computing consists of three levels from the bottom to the top: infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS). Today, linking traditional social content and web services to the cloud is becoming increasingly important, as doing so can scale up automated information processing capabilities and achieve striking results with a high efficiency through parallel and distributed computing techniques [17]. Based on the mature PaaS – Heroku [18], we develop a cloud platform of Social Drive, to manage and coordinate the synchronization, authentication and dissemination (upon Facebook) of diverse real-time VSN related data uploaded from Social Drive running on mobile devices onboard vehicles.

3. SYSTEM OVERVIEW

As shown in Figure 2, the overall architecture of the Social Drive system consists mainly of three parts: the Social Drive mobile platform, Social Drive cloud platform, and Social Drive web application on Facebook. The mobile platform of Social Drive gathers the streaming data from the OBD readers of the vehicles that users are driving, analyzes the data and provides driving feedback to users. The cloud platform of Social Drive provides a central coordinating platform to store the diverse data uploaded from Social Drive on mobile devices, as well as automatically posting such data to Facebook. The Social Drive web application is deployed as a web application on Facebook, which assists users to view, post and comment on trip information and experience from their friends and/or themselves on the Facebook website.

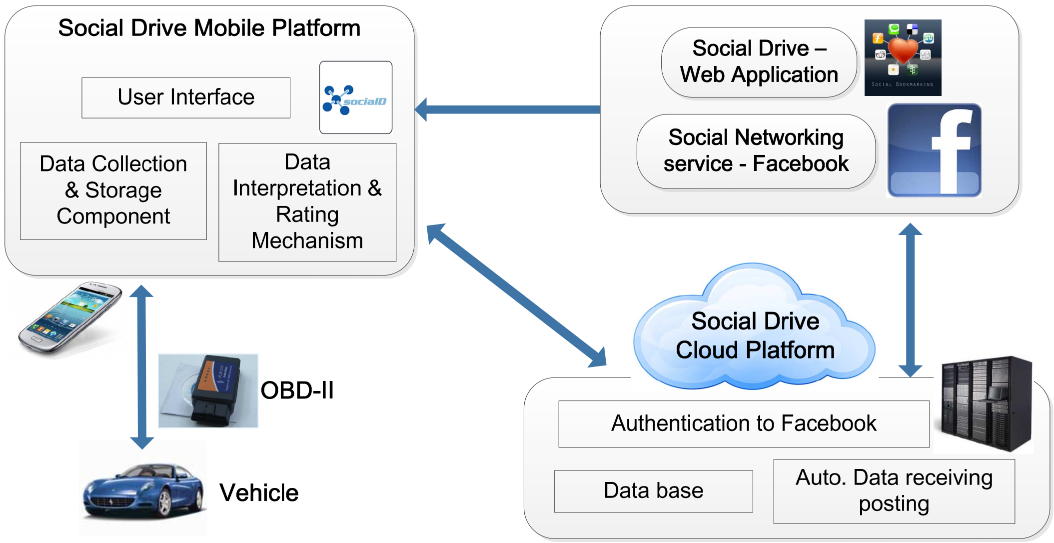

Figure 2. System architecture of Social Drive

3.1 Social Drive - Mobile Platform

The Social Drive mobile platform is run as a mobile application on common Android mobile devices, and it consists of three components: data collection and storage, data interpretation and rating mechanism, and UI of Social Drive mobile application. The data collection and storage components are developed based on Torque [19], which is an existing application that will be presented in more details in Section 4.1.

A. Rating mechanism of Social Drive mobile application

With rising gas prices and increasing maintenance costs, fuel economy is now a key selling point for any type of vehicle. Thus, in Social Drive, we aim to design a mechanism that could help users to improve their driving behavior, and reduce the vehicle fuel consumption and the financial burden of car ownership. Furthermore, according to Transport Canada, stop and start driving increases vehicle fuel consumption and toxic gas emissions [20]. As stop and start driving is inevitable within the city, one of the ways of reducing fuel consumption would be to minimize the amount of acceleration that is required to get up to city speed limits. A similar principle is used in a number of new vehicles that comes with an "eco" mode. Consequently, here we focus on the acceleration assessment and overall user assessment of vehicles.

In order to design a reasonable rating mechanism, we first ran a short test loop that had a combination of moderate and hard acceleration episodes. After a number of trial runs and attempts at analyzing the collected data, we found that the combination of throttle input and engine speed (measured in rounds per minute, RPM) allowed us to detect hard acceleration with a fair degree of accuracy. Using a Python script, we found that hard acceleration had typically occurred when the change in throttle input within a 2 second period was greater than 10% and the change in engine RPM within the same period was greater than 500 RPM. Thus, in our rating mechanism, the driving behaviour of the users will be evaluated based on the three main criteria: the number of hard acceleration episodes relative to the distance travelled, the ability to achieve a targeted average fuel economy figure, and the ability of the driver to follow the recommended servicing date suggested by the application. The equation below is used to determine the overall rating of the users:

$$Score = (D/HA) \cdot (E/TE) \cdot (S)$$

Score	Rating
< 0	F
0 - 0.5	D
0.5 - 1.0	C
1.0 - 2.0	B
2.0 - 3.0	A-
> 3.0	A

- HA = Total number of hard accelerations recorded
- D = Total distance travelled
  - o If HA = 0, HA = 1
- TE = Targeted average fuel economy (10L/100km was chosen)
- E = Actual average fuel economy
- S = Servicing status
  - o If service is overdue, S = 0.7
  - o If service is due today, S = 1.0
  - o Otherwise, S = 1.3

Figure 3. The grading criteria of Social Drive for assessment

The primary weight of the scoring mechanism is on the D/HA value with the scaling factors E/TE and S. This is because HA/D has the greatest tendency of increasing the score. The servicing status variable S is capable of scaling the overall rating by a factor of 1.3. Based on the score that is achieved, a letter grade will be assigned, which is shown in Figure 3.

Moreover, one shortcoming of our method is that the accuracy may decrease when it is applied to a vehicle with a higher displacement engine. Because a vehicle with a higher displacement engine typically requires less throttle input and engine RPMs to reach city speeds, the assessment criteria in some situations may not be able to detect instances of hard acceleration.

B. User interface of Social Drive mobile application

Considering that there is a very limited amount of screen real estate in most of the current smartphones, and Social Drive is intended to run in the vehicular environments, we adopt a tab-based interface that can be controlled by a simple swipe gesture. As shown in Figure 4, the UI of Social Drive mobile application mainly consists of three fragments: (a) Friend Activities, (b) Personal Statistics, and (c) Saved Trips. In addition to the fragments of the tab interfaces, a setting interface is provided and

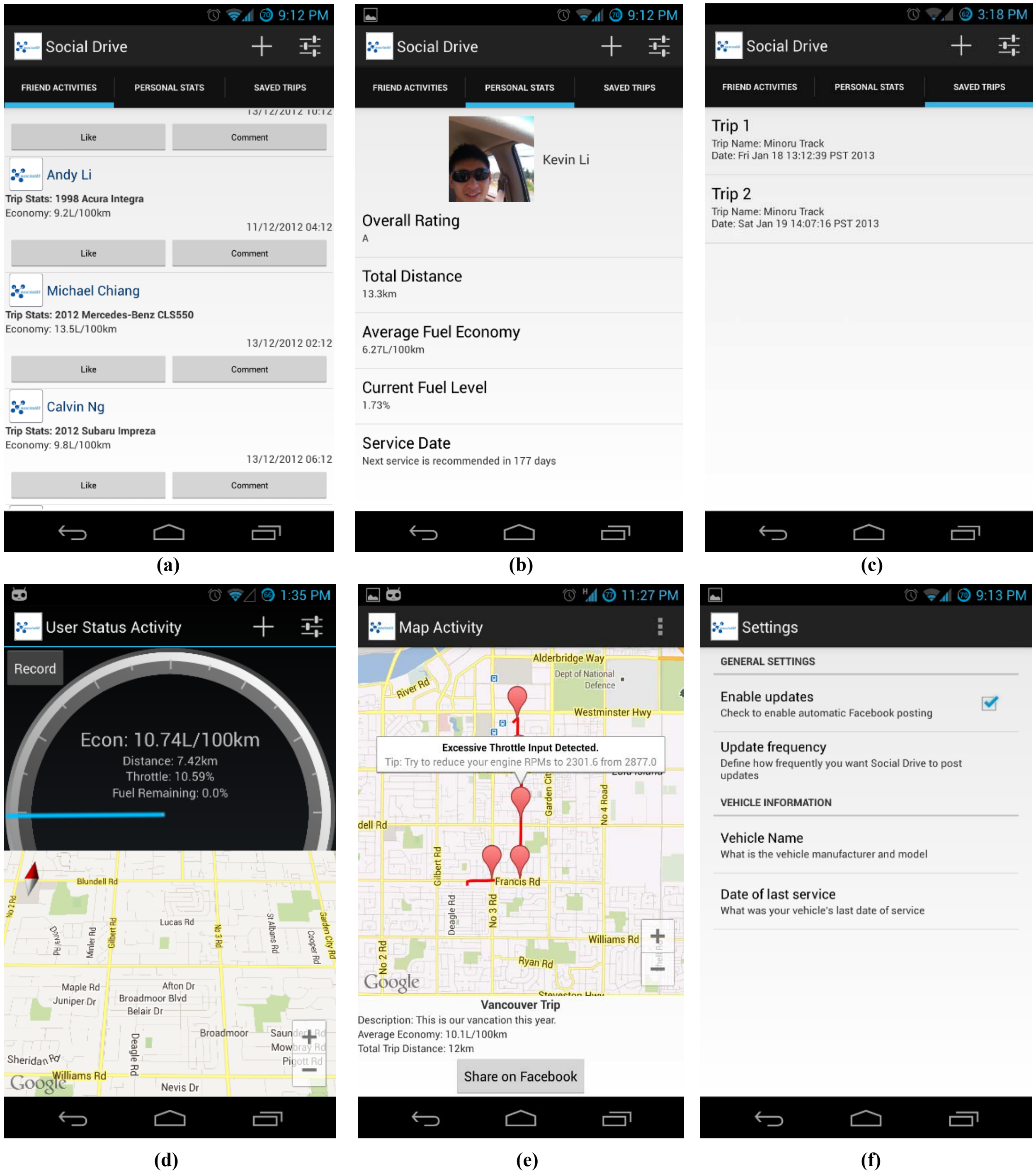

Figure 4. Screen-shots of the Social Drive user interface

shown in Figure 4(f)), which enables the users to make some personalized configurations, such as whether to automatically upload the data to Facebook, and the frequency of such operation, etc. Moreover, based on the rating mechanism we discussed above and the Google map services, Social Drive provides the user status activity shown in Figure 4(d), and map activity shown in Figure 4(e), which respectively enables the users to see their real-time driving status, and provides feedbacks to improve their driving behaviors so as to reduce fuel consumption.

3.2 Social Drive - Cloud Platform

The cloud platform of Social Drive works as a bridge between the Social Drive mobile platform and Social Drive web application on Facebook. It provides a database to store and manage the diverse trip and driving information uploaded from Social Drive on mobile devices. Also, it provides a free web hosting service for running the web application of Social Drive, which can be used to get the authentication of Facebook, and automatically post the trip information of Social Drive for the users' Facebook friends.

3.3 Social Drive – Social Web Application

The social web application of Social Drive is developed and deployed based on Facebook. As shown in Figure 5, it mainly provides three functions to users: (i) provides custom actions and aggregations for posting trips on their time-line using Facebook open graph; (ii) provides a personal log for keeping track of trip progress and driving experiences; and (iii) enables users to view friends' trips and driving experiences as news feeds.

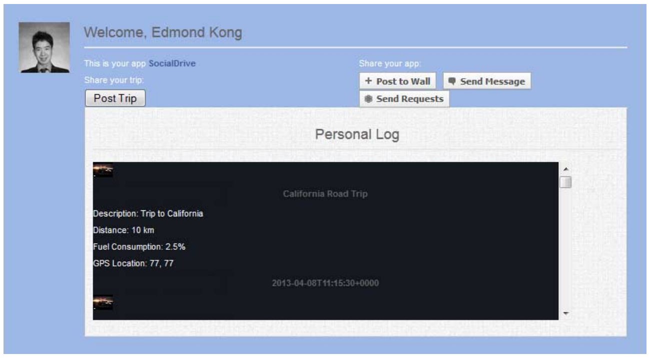

Figure 5 (a). User interface of the Social Drive – social web application

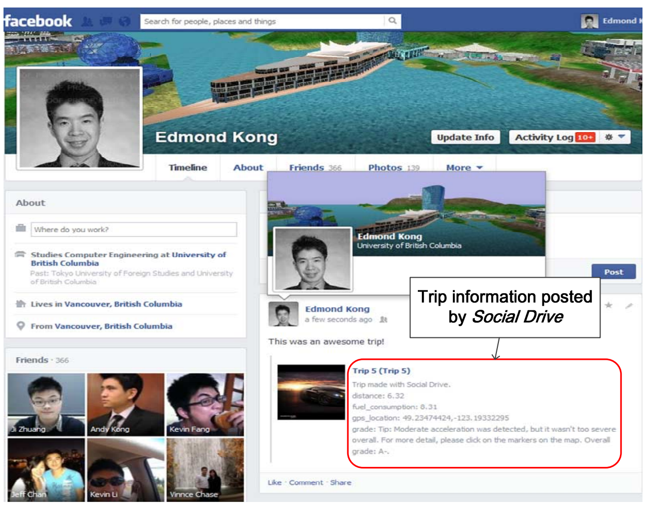

Figure 5 (b). User interface of the Social Drive – social web application

4. IMPLEMENTATION STRATEGIES

As introduced in Section 2, the current version of Social Drive is implemented based on the Android system. In this section, we discuss and present the practical implementation methodologies of the main components of the Social Drive system.

4.1 Vehicular Data Collection and Storage

To collect the streaming vehicular data in real-time, we deploy a Bluetooth enabled OBD II reader as hardware module that connects to the OBD port in the vehicle, and adopt Torque [19] as the supporting software on the mobile device to connect with the OBD II and gather the vehicular data from it.

Furthermore, as a significant amount of vehicular data will be collected during a trip by the Social Drive, thus a local storage medium is needed for storing such data. Also, due to the number of different tabs and activities within the Social Drive, the storage medium also needs to be accessible throughout the entire application. Considering the capacity of mobile devices, we adopt an SQLite database for the data storage of Social Drive, and enable developers to perform database and Google Maps-oriented interactions efficiently.

To create and manage a local database, we need to implement our own version of a *SQLiteOpenHelper* object. The *onCreate* function of the *SQLiteOpenHelper* class must be overridden in order to include the SQL query that is needed to create the database. The entity-relationship diagram that is used for the database is shown in Figure 6. For instance, Figure 7 shows the code snippets to create a new instance of the *ContentValues* variable in order to insert or update values of the database. Sets of values can be stored in *ContentValues*. The insert function of the *SQLiteDatabase* class is then called, processing the contents of the *ContentValues* variable and inserting or updating the processed values into the application's local database.

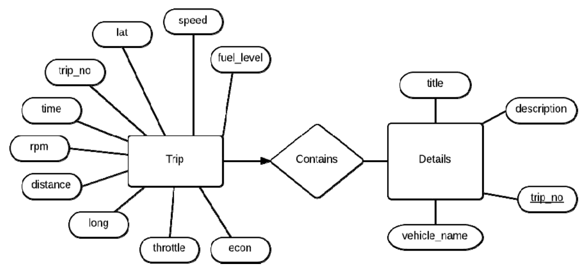

Figure 6. Entity-relationship diagrams of the Social Drive mobile database

```
SQLiteDatabase db =
this.getWritableDatabase();
 …
ContentValues desc = new
ContentValues();
desc.put(KEY_TRIP, trip.getTripNo());
desc.put(KEY_TITLE, "Trip " +
trip.getTripNo());
desc.put(KEY_DESCRIPTION, "");
db.insert(TABLE_TRIP_DETAIL, null,
desc);
```

Figure 7. Code snippets for inserting data entries into the table

Moreover, whenever a database access is required, an instance of the *DatabaseHelper* object is created first. Using the functions of the *DatabaseHelper* object, the data entries of the database can be added, modified, or removed. For Social Drive, we are required to use two main tables for storing the data collected from the vehicle's OBD-II port: the Trip table and the Details. The primary function of the Trip table is to store the raw data that is collected from the vehicle's OBD-II port.

4.2 Mobile Social Application

As demonstrated in Section 3.1-B, the Social Drive mobile application consists of various functions with different UI. Thus, to implement such functions, the corresponding activities (on Android) need to be specified. The flow chart of the activities for the implementation of the Social Drive's UI is shown in Figure 8.

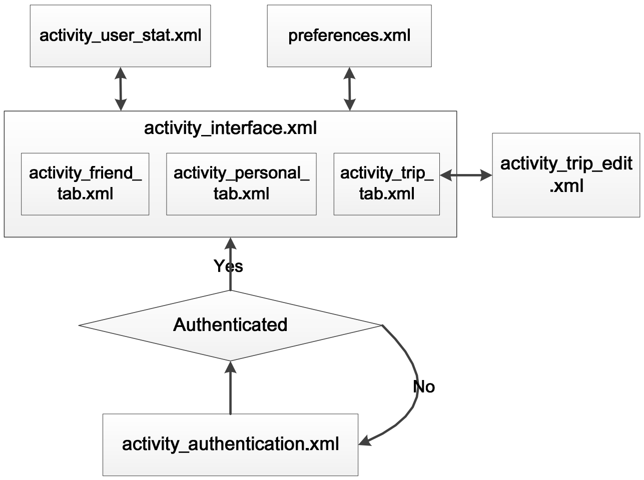

Figure 8. The flowchart of the user interfaces of Social Drive

4.3 Social Web Application

The implementation and deployment of the Social Drive web application is based on the PaaS cloud platform – Heroku [18]. One of the major challenges to make the web application of Social Drive run on this platform and update data to the remote repository is the authentication of the secure shell (SSH) key, but it could be approached by manually configuring the SSH configuration file and setting the correct path to the SSH key.

5. EVALUATIONS

In this section, we evaluate the performance of Social Drive in practical scenarios in three aspects: time latency, networking overhead, and battery consumption. The experimental devices we used are: Vehicle - 2005 Toyota Sienna; ELM327 Bluetooth OBD-II Module; and Smartphone - Google Nexus 4 and Samsung Galaxy S2.

5.1 Time Latency

In this part, we evaluate the time latency when running Social Drive on smartphones in two aspects: **a.** initial launch time of Social Drive on smartphone; **b.** time latency when posting a message from Social Drive in smartphone to Facebook. The experimental smartphone we used here is a Samsung Galaxy S2.

We monitor the launch time of Social Drive on the Samsung Galaxy S2 with ADB logcat in five data sets, and then calculate the average time. The results are shown in Table 1. It is found that Social Drive could be quickly launched within 1s, and the average time is 833ms.

Table 1 Initial launch time of Social Drive

Data set	1	2	3	4	5	Avg.
Time	831ms	901ms	931ms	751ms	751ms	833ms

On the other hand, the time consumed for posting a trip from Social Drive to Facebook normally takes about 2s.

5.2 Networking Overhead

In this part, we evaluate the networking overhead of Social Drive in three aspects: **a.** first load of Social Drive with Google Map; **b.** relocation and zooming after driving in a period; and **c.** posting trip information. The results are shown in Figure 9, Figure 10, and Figure 11, respectively.

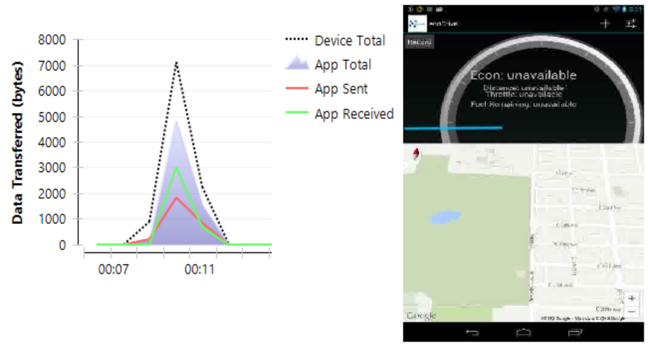

Figure 9. Networking overhead of Social Drive – first load

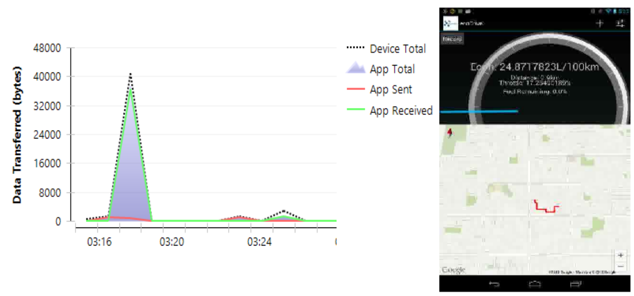

Figure 10. Networking overhead of social drive – in driving period

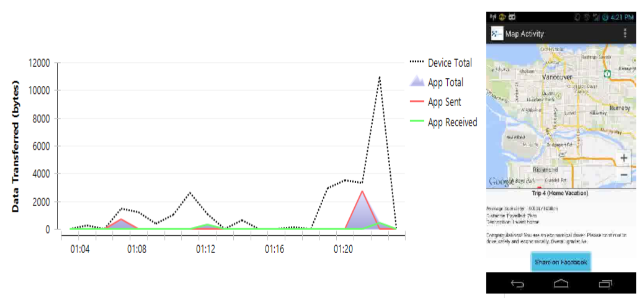

Figure 11. Networking overhead of Social Drive – posting trip

5.3 Battery Consumption

In this part, we evaluate the battery consumption of running Social Drive on some popular smartphones. In the experiment, we considered two cases: **Case 1**, battery consumption to start up Social Drive and use it to browse and post trip data without Torque running in the background; **Case 2**, battery consumption for real time monitoring and trip data recording by Social Drive with Torque running in the background. The smartphone used in these experiments is a Google Nexus 4 running Android 4.2.2.

Case 1

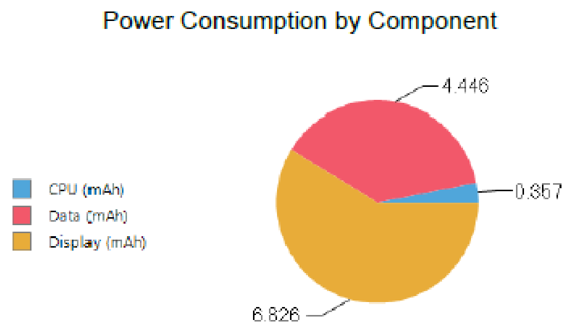

Figure 12. Statistic of battery consumption – case 1

Table 2. Battery consumption of Social Drive - case 1

Time period	Foreground: 2 m 50s Background: 27s
Foreground battery consumption	19.83 % , power: 11.6 mAh
Background battery consumption	.3 % (power - .03 mAh
Social Drive total running power	11.63 mAh
Social Drive average CPU usage	4.58 %

Case 2

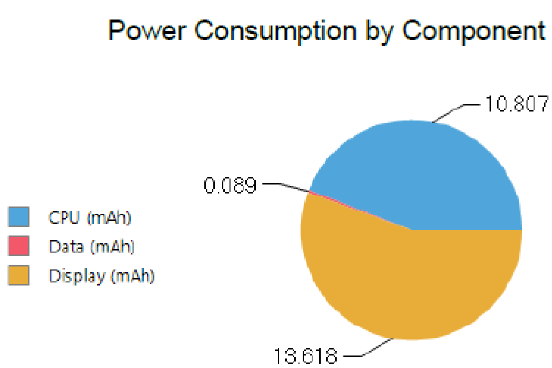

Figure 13. Statistic of battery consumption – case 2

Table 3. Battery consumption of Social Drive - case 2

Time period	Foreground: 5 m 5s Background: 0s
Foreground battery consumption	20.78 % , power: 24.51 mAh
Background battery consumption	N/A
Social Drive total running power	24.51 mAh
Social Drive average CPU usage	22.8%

The results are shown in Figure 12 and Table 2, and Figure 13 and Table 3, respectively. We found that the battery consumptions per minute are comparable for the two cases, as the battery consumption is mostly contributed by the screen display of the smartphone. However, the CPU usage is significantly increased in case 2, which may impact the processing speed of other tasks. Considering that in a vehicular environment, the driver cannot normally interact with other applications on their smartphones when they are driving, thus the increase of CPU usage when running Torque (to support the real-time data collection of Social Drive) should not be a major concern.

6. RELATED WORK

There has been much research works done for the mobile social applications for green transportations. For example, [8] proposes UbiGreen, a mobile application that could semi-automatically senses the information about transportation behavior, and give users feedback about sensed and self-reported transportation behaviors through their mobile devices. A navigation service called GreenGPS was presented in [21], based on the context information from OBD II, which provides a hierarchy of models that could estimate the most fuel efficient routes for vehicular users. Using the concept of service-oriented architecture, a service-oriented VSN platform for transportation efficiency called VSSA was proposed in [22].

RoadSpeak [23] is the first framework proposed for VSNs, which allows commuters to automatically join voice chat groups on roadways. Unlike traditional social networks, RoadSpeak considers, in addition to the interests of users, the time interval and location in its definition of the VSN profile when user groups are formed. RoadSpeak partially supports extensibility. It provides a number of Java APIs to application developers, based on which developers can extend RoadSpeak clients to provide enhanced functionality. Partly inspired by but different from RoadSpeak, Social Drive leverages the advantages of Facebook, a popular social network, to provide a user-friendly mobile application to common vehicular users, thus reducing the barrier to mass adoption.

Moreover, security and privacy is always a concern for VSN based mobile applications [24]. A number of solutions exist in the literature that could be adopted to address such concerns. For instance, the authors in [25] proposed a vehicular network trust model that integrates cryptography-based entity trust and email-based social trust, where the entity trust provides security protections (i.e., origin and data integrity) and the social trust provides a level of belief in the transmitted data. On this basis, they adopt identity based cryptography to integrate entity trust and social trust so as to deploy a unique identity to each entity, and use their attributes to develop secure group communications. The authors in [26] presented a trust architecture and model situation-aware trust to address several important trust issues in vehicular networks that depend on the Internet infrastructure. These different mechanisms can be adapted and integrated with Social Drive to achieve different levels of security.

7. CONCLUSIONS

In this paper, we have presented Social Drive, a crowdsourcing-based VSN system for green transportation. Social Drive leverages the advantages of cloud computing and commercial social network – Facebook, incorporates a novel rating mechanism about fuel economy of users, and provides a seamless and economic solution with a user-friendly mobile application to users. It enables the vehicular users to be aware of their driving behaviors and share their real-time trip information through widely used social networks conveniently, which can stimulate and improve their driving habits in a fuel economic way towards green transportation. Our practical experiments have demonstrated that Social Drive can be used in practical scenarios, and runs with a considerable time efficiency, low battery consumption and low networking overhead on some popular mobile devices. These experiments not only verify the feasibility of Social Drive, but also provide practical experience that inspires the future research and development of mobile social applications for green transportation. To the best of our knowledge, Social Drive provides the first comprehensive and practical solution that investigates the real-world development and deployment of mobile social applications for green transportation.

In further development of the Social Drive system, we plan to investigate and develop a prediction mechanism. Based on the context information, e.g., the previous occurrences of certain events in the vehicular environments, movement history of vehicles, and streets/roads conditions, this mechanism could enable the gathered information to be used by the drivers or the cars themselves to prevent the excessive accelerations when driving.

8. ACKNOWLEDGMENTS

This work is supported in part by the Canadian Natural Sciences and Engineering Research Council through the DIVA Strategic Network, and by TELUS and other industry partners. The authors would like to acknowledge the support of Dr. Maria Toeroe of Ericsson Canada for reviewing the work and suggesting improvements of this paper.

9. REFERENCES

[1] L. Han, S. Smaldone, P. Shankar, J. Boyce, and L. Iftode. Ad-hoc voice-based group communication. In *Proc. IEEE PerCom*, pp. 190-198, 2010.

[2] C. Boldrini, M. Conti, and A. Passarella. Impact of Social Mobility on Routing Protocols for Opportunistic Networks. In *Proc. IEEE WoWMoM*, pp. 1-6, 2007.

[3] R. Fei, K. Yang, and X. Cheng. A cooperative social and vehicular network and its dynamic bandwidth allocation algorithms. In *Proc. IEEE INFOCOM*, pp. 63-67, 2011.

[4] A. Miklas et al. Exploiting Social Interactions in Mobile Systems. In *Proc. ACM Ubicomp*, pp. 409-428, 2007.

[5] F. Li, and Y. Wang. Routing in vehicular ad hoc networks : A survey. *IEEE Vehicular Technology Magazine*, vol. 2, no. 2, pp. 12-22, 2007.

[6] E. Hossain et al. Vehicular Telematics Over Heterogeneous Wireless Networks: A Survey. *Computer Communications*, Elsevier, vol. 33, no. 7, pp. 775-793, 2010.

[7] X. Hu, T.H.S. Chu, H.C.B. Chan, and V.C.M. Leung. Vita: A Crowdsensing-Oriented Mobile Cyber-Physical System. *IEEE Trans. Emerging Topics in Computing*, 1(1), 2013.

[8] J. Froehlich, T. Dillahunt, P. Klasnja, J. Mankoff, S. Consolvo, B. Harrison, and J. Landay. UbiGreen: investigating a mobile tool for tracking and supporting green transportation habits. In *Proc. ACM CHI*, 2009.

[9] S. Smaldone, C. Tonde, V. Ananthanarayanan, A. Elgammal, and L. Iftode. The Cyber-Physical Bike: A Step Towards Safer Green Transportation. In *Proc. ACM Hotmobile*, 2011.

[10] R. Ganti, N. Pham, H. Ahmadi, S. Nangia, and T. Abdelzaher. GreenGPS: a participatory sensing fuel-efficient maps application. In *Proc. ACM MOBISYS*, 2010.

[11] G. Maia, A.L.L. Aquino, A. Viana, A. Boukerche, and A. A.F. Loureiro. HyDi: a hybrid data dissemination protocol for highway scenarios in vehicular ad hoc networks. In *Proc. ACM DIVANet '12*, pp. 115-122, 2012.

[12] Android operating system, 2013, available: http://developer.android.com/index.html

[13] A. Toninelli et al., Middleware Support for Mobile Social Ecosystems. In *Proc. IEEE 34th Annu. Computer Software and Applications Conf. Workshops*, 2010.

[14] Facebook, 2013, available: http://www.facebook.com/

[15] N. B. Ellison, C. Steinfield, and C. Lampe. The Benefits of Facebook "Friends:" Social Capital and College Students' Use of Online Social Network Sites. *Journal of Computer-Mediated Communication*, vol. 12, no. 4., pp. 1143-1168, July 2007.

[16] L. J. Zhang, and Q. Zhou. CCOA: Cloud Computing Open Architecture. In *Proc. IEEE ICWS*, pp. 607-616, 2009.

[17] G. Demartini, D.E. Difallah, and P. Cudr´e-Mauroux. ZenCrowd: leveraging probabilistic reasoning and crowdsourcing techniques for large-scale entity linking. In *Proc. WWW*, pp. 469-478, 2012.

[18] Heroku, 2013, available: https://www.heroku.com/

[19] Torque, 2013, available: https://play.google.com/store/apps/details?id=org.prowl.torque

[20] Driving tips to improve your fuel consumption, 2013, available: http://www.tc.gc.ca/eng/programs/environment-fcp-tips-678.htm

[21] Raghu K. Ganti, Nam Pham, Hossein Ahmadi, Saurabh Nangia, and Tarek F. Abdelzaher. GreenGPS: A Participatory Sensing Fuel-Efficient Maps Application. In *Proc. ACM MOBISYS*, 2010.

[22] X. Hu, V.C.M. Leung, and W. Wang. VSSA: a service-oriented vehicular social-networking platform for transportation efficiency. In *Proc. ACM DIVANet '12*, pp. 31-38, 2012.

[23] S. Smaldone, L. Han, P. Shankar, and L. Iftode. RoadSpeak: Enabling Voice Chat on Roadways using Vehicular Social Networks. In *Proc. ACM SocialNets*, 2008.

[24] P. TalebiFard, and V.C.M. Leung. A content centric approach to dissemination of information in vehicular networks. *In Proc. ACM DIVANet '12*, pp. 17-24, 2012.

[25] D. Huang, Z. Zhou, X. Hong, and M. Gerla. Establishing Email-Based Social Network Trust for Vehicular Networks. In *Proc. IEEE CCNC*, 2010.

[26] X. Hong, D. Huangy, M. Gerlaz, and Z. Cao. SAT: situation-aware trust architecture for vehicular networks. In *Proc. ACM SIGCOMM workshop*, pp. 31-36, 2008.