Context-aware Information Management in the Green Move System*

Extended Abstract

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Abstract. The Green Move project aims at realizing a zero-emission-vehicle (ZEV) sharing service that also includes pervasive information management. In this paper we discuss the use of context-aware techniques applied to data gathering, shared services and information distribution, and how they lead to the reduction of (noisy) information delivered to users and to the personalized, privacy-aware distribution of information among the various system's users.

1 Introduction

Nowadays technologies enhance most aspects of everyday life. A technology which is seamlessly integrated in our way of living is called pervasive [11]. Pervasive technologies generate huge amounts of data, coming from possibly large collections of participating entities forming complex systems; this data have to be collected, re-distributed and analyzed in a reasonable amount of time, to obtain useful and up-to-date information.

Such a scenario is instantiated in the *Green Move* [7] project (http://www.greenmove.polimi.it), whose aim is a zero-emission-vehicle (ZEV) sharing service for the city of Milan. In Green Move the core services are surrounded by a social-like platform to support users in a large urban context. The ZEV-sharing service provides four different *service configurations*, designed to meet different user-category requirements: a) **condo-sharing** for users who live in apartments and decide to share a (set of) vehicle(s); b) **firm-sharing** for firms outsourcing their company vehicles to the Green Move sharing service; c) **world-of-services** users use a Green Move vehicle to reach a registered place (an *aggregation point*) offering dedicated services; and d) **generic** users whose needs do not match any of the previous configurations, but a traditional vehicle sharing service.

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The Green Move system also aims at providing an integrated user experience among core and accessory services, like information distribution and advertising based on users' interests and positions. To fulfill these objectives we propose a context-aware approach to realize and manage situation-dependent services and support the processing of data flows to extract interesting information. The approach drives the data flows since its gathering phases, even from sensors, selectively retrieving data only in quantity and format useful according to the actual context: e.g. driving downtown is different than driving in the suburbs, thus the user reasonably expects different information –like traffic density or the presence of restricted areas– and with different frequencies.

The paper is organized as follows: we present the data management subsystem of Green Move in more detail in Section 2; a perspective about how context is modeled in our approach is presented in Section 3 and specific applications of the proposed approach in Section 4. Conclusions and future work are presented in Section 5.

2 Green Move Information Management Architecture

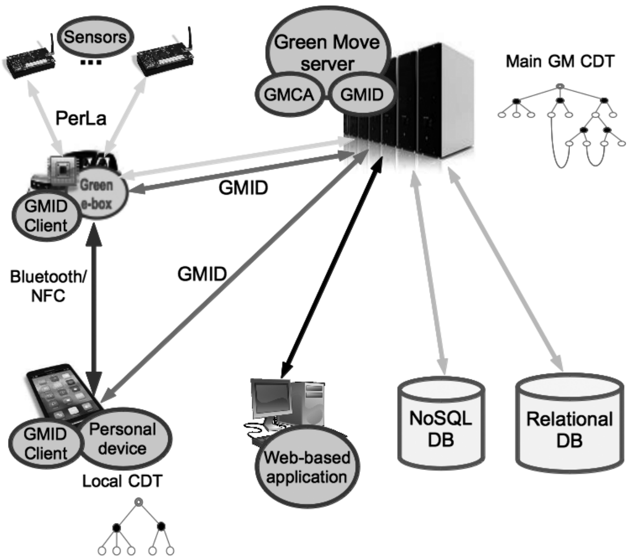

Fig. 1. The Green Move data management system architecture

The architecture of the Green Move system envisages three main components (see Fig. 1): *1)* a central platform designed to manage infrastructural aspects, data storage and information flows, *2)* on-vehicle components (*Green e-Box*) and *3)* the users' personal devices (smartphone or equivalent). The central platform comprises the *GMCA* (Green Move Context-Aware) and the *GMID* (Green Move Information Distribution) modules to handle vehicle reservation and assignment, web services, user experience personalization, and information distribution in the whole system.

The Green Move server provides services and data to support security, traffic and vehicle management, from door unlocking to GPS navigation, while the Green e-Boxes provide local data analysis and an interface to the Green Move system. In particular, the Green e-Box gathers and possibly pre-processes data from sensors before sending them to the Green Move server, and displays[1] useful information about the trip to the users. The user personal device interacts both with the Green e-Box, for locking/unlocking doors, starting the engine, etc. by means of a *Bluetooth/NFC* connection, and with the Green Move server by means of the GMID to display useful ads and information. Table 1 represents the core DB of the Green Move system. Data are stored in a relational database, except for GPS and other sensors data, stored in a NoSQL DB.

VEHICLE(id, seats number, insurance, pub_key, engine_type, *model, owner*)
USER(id, name, surname, birthdate, gender, email, pub_key, ident_url, username, passwd, VAT_info, billing_info, is_owner, is_customer)
GREEN_EBOX(id, *vehicle id*)
GPS(ts, *gb_id* , latitude, longitude, gps_speed, n_satellites)
RESERVATION(id, picking_ts, release_ts, picking_position, release_position, *vehicle_class*, *fare*, confirmed, planned_travel_dist, *service_conf*, *user_id*)
ASSIGNMENT(*reservation_id* , *vehicle_id*, confirmed)

Table 1. Main tables in the Green Move database

Running Example To give some practical examples we refer to the following simple scenario. ‘‘Mr. Guido Verde’’ has registered to a Green Move condo-sharing facility available at his condo, which includes a parking lot with a recharging station. Once registered, he decides to take full advantage of all services; he specifies his data to the system and downloads the Green Move application to his smartphone filling the private (local) part of his profile. Besides more occasional usages, Mr. Verde typically uses the electric cars to take his granddaughter to school every morning, and sometimes stops, on the way home, at the supermarket for some shopping. Thanks to his private profile in the GMID client on his smartphone, Mr. Verde is also able to receive interesting traffic information and ads according to the topic he selected.

3 Modeling Context in Green Move

In Green Move, context is modeled by means of the Context Dimension Tree (henceforth simply CDT). As described in detail in [3], the CDT complements conceptual data modeling with a formalism describing all the possible contexts [6] envisaged by the designer. The CDT represents an application-dependent set of dimensions characterizing the database users and the environment surrounding them. Specific features

[1] If the Green e-Box is not supplied with a display, this function can be performed by the user personal device.

of the Green Move scenario have driven some interesting innovations, reported in the following.

The CDT of Fig. 2 represents the dimensions (black nodes) and their possible values (white nodes) envisaged to contextualize Green Move data and car services (see Section 4.3). A *context element ce* is built assigning a value or a parameter to a dimension, and a *context* is defined as a conjunction of context elements as in Fig. 2.

3.1 Local CDTs

The Green Move application needs, especially with respect to privacy, triggered an innovation in the CDT context-modeling approach. Indeed, it seems appropriate that the private profile and specific needs and tastes of a Green Move customer should be unknown to the Green Move server, resting within the user personal device. In this case, we need to distribute the context data to different locations, leading to the introduction of a *combined CDT* comprising a *primary CDT* and one or more *local CDTs*.

A local CDT in the Green Move system is maintained locally to user devices and is used to complete the context-based data filtering. For each Green Move customer, the system will compose a specific combined CDT from the primary one, maintained by the server, and the local one, available on the personal device.

The composition of a local CDT with a primary one must comply with the CDT design constraints described in detail in [2]. In the CDT of Fig. 2, the dimension *Local_conf* has as possible values the roots of the local CDTs. A *combined context CC* of a combined CDT is then easily defined as the conjunction of a context CP of the primary CDT and a context CL of a local CDT, and thus it is nothing more than a conjunction of their context elements (*ce*):

$$CC = CP \wedge CL = \bigwedge_{i=1}^{n} ce_i \wedge \bigwedge_{h=1}^{m} ce_h = \bigwedge_{k=1}^{m+n} ce_k$$

4 Context-awareness in Green Move

There are three main tasks for which a context-aware approach is applied in the Green Move project: (1) producing a personalized user experience, which involves the management of the whole system and the interaction with users, (2) sensors data retrieval and evaluation and (3) information distribution. Tasks (1) and (2) are performed by the GMCA, while task (3) by the GMID.

4.1 Personalized User Experience

Due to the user-centered perspective of the Green Move project, context-aware techniques are used to tailor the user experience against the users' actual context. Referring to the running example, we follow Mr. Verde, who has just logged into the web interface to the Green Move system. He is making a reservation for a car to be used the next morning to take his grandchild to school. Since Mr. Verde performs the same reservation every morning, the system is able to guess that he may need a child seat by analyzing the actual context and the previous contexts.

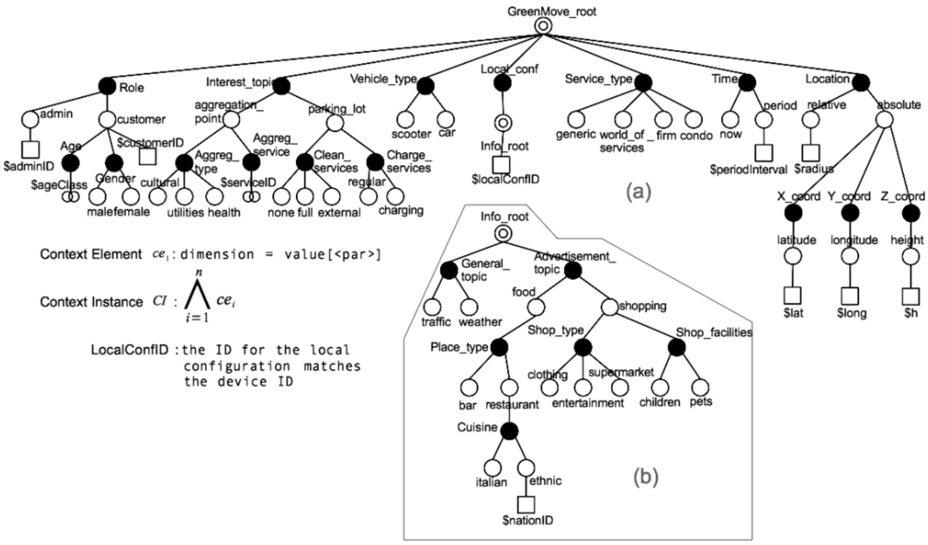

Fig. 2. The primary (a) and local (b) CDTs designed for the Green Move project

Contextual preferences are used to rank data and services, according to the interests demonstrated by the users in different contexts; for instance, Mr. Verde will be offered a children's seat whenever he tries to reserve a car in the morning.

This analysis is performed automatically by using the *contextual preference-mining* framework (PreMINE) [8,1]. With PreMINE, instead of requiring users to answer a large set of questions about their interests and preferences in each possible context, the system uses data mining techniques to extract and learn them directly from historical data.

Once Mr. Verde gets into the car and starts driving around the city, the GMID service is able to identify useful information (traffic jams, street works in progress, ...) with respect to the context data fed to the system (e.g. values for location and time dimensions). The pertinent information is provided to the vehicle Green e-Box, to be displayed on its screen (if present) or on Mr. Verde's smartphone running the client.

4.2 Context-aware Sensors

Since frequent data transmission is the most energy-consuming operation and can bring to network congestion, operations on the sensed data (e.g. data aggregation) can be performed locally on the sensing nodes, which can send larger packets at lower frequency, instead of small sets of possibly redundant values [4]. However timeliness constraints might be strong and, in this case, the transmission protocol should ensure a good compromise for a proper real-time behavior of the system (e.g. key data about road events should always be transmitted as soon as available).

To manage the data produced by sensors, we use the *PerLa* (*Pervasive Language*) framework [9] for its SQL-like sensor-querying language, its high adaptability to different types of sensors and the transparency of the underlying network configuration. Moreover, PerLa supports context-awareness abilities [10] and can be integrated in a general context-aware system based on the CDT framework.

In our scenario, the data gathering process starts from the moment Mr. Verde unlocks the doors of the assigned vehicle and continues until he gets out of the vehicle releasing it and making it available for the next reservation (the data gathering process restarts for the next user). The whole process is context-mediated by means of PerLa, collecting only data useful for the current user and vehicle context. The data gathered locally from sensors on the vehicle (gps position, speed, actual power consumption, ...) are pre-processed by the Green e-Box (on which a PerLa module runs) and part of the computation (possibly aggregation) is done by this component. From Green e-Boxes data are pushed to the Green Move server (both to the GMCA and GMID).

After declaring the CDT as described in [10], PerLa allows the user to declare the activities that the system must perform at run-time when a context becomes active. For instance, Mr. Verde can drive in two different zones of the city: downtown, where battery charging stations are close to each other, or in the suburbs, where they are located farther away. Whether Mr. Verde is driving downtown or not is detected by his GPS position within an offset from the city center. To give him the needed information, we define in tables 2 and 3 two different context-aware PerLa procedures:

- **Driving in the suburbs** (Table 2) this context will be enabled only if this precondition is true; in this case, the system will sample position and battery charge every 60 seconds if the charge is <= 50%, only if the vehicle is moving, speed and battery charge data; if the charge is <= 35% an alarm is set and the system will display the nearest charging station.
- **Driving downtown** (Table 3) if this context is enabled, the system will sample position and battery charge every 120 seconds if the charge is <= 50%, only if the vehicle is moving, speed and battery charge data; if the charge is <= 35% an alarm is set and the system will display the nearest charging station.

It is possible to see how computation can be distributed among the system components: all the considerations about battery charge are executed locally, sending data to the Green Move server if and only if all the required conditions are satisfied (*speed* > 0 AND *batt_charge* <= 0.35). The results of the PerLa queries are used to retrieve data from sensors, whenever needed, and to enact an alarm if necessary.

```
CREATE CONTEXT  Suburbs_Driving
  ACTIVE IF  lat > center_lat + max_dist  AND  long > center_long + max_dist
ON_ENABLE:  SELECT  lat, long, batt_charge
  SAMPLING EVERY  60 s  WHERE  batt_charge <= 0.5
  EXECUTE IF EXIST  lat, long, speed, batt_charge  AND  speed > 0
  SET PARAMETER  'alarm' = TRUE  WHERE  batt_charge <= 0.35;
ON_DISABLE:  DROP  Suburbs_Driving;
  SET PARAMETER  'alarm' = FALSE ;
```

```
 REFRESH EVERY  5 m ;
```

Table 2. Suburbs context

```
CREATE CONTEXT  Downtown_Driving
 ACTIVE IF  lat <= center_lat + max_dist  AND  long <= center_long + max_dist
ON_ENABLE: SELECT  lat, long, batt_charge
 SAMPLING EVERY  120 s  WHERE  batt_charge <= 0.5
 EXECUTE IF EXIST  lat, long, speed, batt_charge  AND  speed > 0
 SET PARAMETER  'alarm' = TRUE  WHERE  batt_charge <= 0.35;
ON_DISABLE: DROP  Downtown_Driving;
 SET PARAMETER 'alarm' = FALSE;
 REFRESH EVERY  5 m ;
```

Table 3. Downtown context

4.3 Information Distribution

To tailor and distribute information coherent with users' whereabouts and interests we need a powerful and customizable, yet privacy-safe, distribution service: the GMID. To realize such aim we adopt the *PervAds* framework [5], which, in its original terms, defines a pervasive and privacy-respectful approach to advertising. The framework has been customized to obtain a general distribution channel retaining key privacy aspects. In PervAds privacy control remains (literally) with the user of the system: the local contexts for the users of PervAds remain on the users' devices and are used to filter locally the data from the service.

The distribution service provides messages, that are *service messages* or *ads*. Private data about user contexts are out of the service visibility at all times, thus respecting privacy. In general, the distribution process comprises three steps:

1. on the central server the GMID system performs a *pre-filtering step* of interesting messages for the client using the part of context belonging to the primary CDT (e.g. age, gender, time and distance among client gps position and ad/message geo-localized descriptor);
2. the set of pre-filtered messages is sent to the client (e.g. user's personal device), which perform the *filtering step*, the private part of the matching, using configured interest topics (local CDT context);
3. finally, the client displays only messages matching the local CDT criteria: overall, the information has been filtered according to the combined CDT.

The message (like traffic data) is composed of three parts: *i)* a short caption, *ii)* an (optional) image and *iii)* a data structure (e.g. an XML-like file) describing the topics related to this specific ad or information (chosen among the ones described in the local CDT). The party who wants to broadcast a context-aware message simply uploads it to an appropriately conceived Green Move web page, and provides metadata about time duration, geospatial information and other possible topics.

Resuming the running scenario, Mr. Verde configures his local client with interest topics (e.g. *General_topic = traffic* and *Cuisine = ethnic<chinese>*) so that it will be able to provide only the messages matching those criteria.

5 Conclusions and Future Work

In this paper we introduced a context-and-preference-aware information collection/dissemination service for the Green Move project based on the Pervasive Language PerLa and the personal advertising platform PervAds, which allow to provide the right information to the right person at the right moment.

References

1. D. Beretta, E. Quintarelli, and E. Rabosio. Mining context-aware preferences on relational and sensor data. In F. Morvan, A. M. Tjoa, and R. Wagner, editors, *DEXA Workshops*, pages 116-120 . IEEE Computer Society, 2011.
2. C. Bolchini, C. A. Curino, G. Orsi, E. Quintarelli, R. Rossato, F. A. Schreiber, and L. Tanca. And what can context do for data? *Comm. ACM*, 52(11):136-140, 2009.
3. C. Bolchini, E. Quintarelli, and L. Tanca. CARVE: Context-aware automatic view definition over relational databases. *Information Systems*, Accepted manuscript (unedited version) available online: 12-MAY-2012.
4. C. Cappiello and F. A. Schreiber. Quality- and energy-aware data compression by aggregation in wsn data streams. *In Proc. of the 2009 IEEE Intern. Conf. on Pervasive Computing and Communications*, PERCOM '09, pages 1-6, Washington, DC, USA, 2009. IEEE Computer Society.
5. L. Carrara and G. Orsi. A new perspective in pervasive advertising. Technical report, Department of Computer Science, University of Oxford, July 2011.
6. A. K. Dey. Understanding and using context. *Personal Ubiquitous Computing*, 5(1):4-7, 2001.
7. G. Alli et al. Green Move: towards next generation sustainable smartphone-based vehicle sharing. In Proc. of SustainIT 2012, 2012. To appear.
8. A. Miele, E. Quintarelli, and L. Tanca. A methodology for preference-based personalization of contextual data. In M. L. Kersten, B. Novikov, J. Teubner, V. Polutin, and S. Manegold, editors, *EDBT*, vol 360 of *ACM Intern. Conf. Proceeding Series*, pages 287-298. ACM, 2009.
9. F. Schreiber, R. Camplani, M. Fortunato, M. Marelli, and G. Rota. PerLa: A language and middleware architecture for data management and integration in pervasive information systems. *IEEE Transactions on Software Engineering*, 38(2):478-496, march-april 2012.
10. F. Schreiber, L. Tanca, R. Camplani, and D. Viganò. Towards autonomic pervasive systems: the PerLa context language. In *Proc. of the 6th Intern. Workshop on Networking Meets Databases co-located with SIGMOD 2011*, June 2011.
11. M. Wieser. The computer for the 21st century. *Scientific American*, 265:94-104, September 1991.