SMART 2013

The Second International Conference on Smart Systems, Devices and Technologies

ISBN: 978-1-61208-282-0

June 23 - 28, 2013

Rome, Italy

SMART 2013 Editors

Michael Massoth, University of Applied Sciences - Darmstadt, Germany

Pascal Urien, Telecom ParisTech, France

SMART 2013

Forward

The Second International Conference on Smart Systems, Devices and Technologies (SMART 2013) held on June 23 - 28, 2013 - Rome, Italy, continues the inaugural event covering tendencies towards future smart cities, specialized technologies and devices, environmental sensing, energy optimization, pollution control and social-cultural aspects.

Digital societies take rapid developments toward smart environments. More and more social services are digitally available to the citizens. The concept of 'smart cities' including all devices, services, technologies and applications associated with the concept sees a large adoption. Ubiquity and mobility added new dimensions to smart environments. Adoption of smartphones and digital finder maps, and increasing budgets for technical support of services to citizens settled a new behavioral paradigm of city inhabitants.

We take this opportunity to thank all the members of the SMART 2013 Technical Program Committee as well as the numerous reviewers. The creation of such a broad and high-quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated much of their time and efforts to contribute to the SMART 2013. We truly believe that, thanks to all these efforts, the final conference program consists of top quality contributions.

This event could also not have been a reality without the support of many individuals, organizations, and sponsors. We are grateful to the members of the SMART 2013 organizing committee for their help in handling the logistics and for their work to make this professional meeting a success.

We hope that SMART 2013 was a successful international forum for the exchange of ideas and results between academia and industry and for the promotion of progress in smart environment technologies.

We are convinced that the participants found the event useful and communications very open. We also hope the attendees enjoyed the historic charm Rome, Italy.

SMART 2013 Advisory Chairs
Wolfgang Leister, Norsk Regnesentral, Norway
Hoyoung Jeung, SAP Research Brisbane, Australia
Petri Koskelainen, Nokia - Sunnyvale, USA

SMART 2013

Committee

SMART Advisory Chairs

Wolfgang Leister, Norsk Regnesentral, Norway
Hoyoung Jeung, SAP Research Brisbane, Australia
Petri Koskelainen, Nokia - Sunnyvale, USA

SMART 2013 Technical Program Committee

Vincent Alimi, University of Caen, France
Luis Alvarez Sabucedo, Universidade de Vigo, Spain
Ryosuke Ando, TTRI (Toyota Transportation Research Institute) , Japan
Petko Bakalov - Environmental Systems Research Institute, USA
Ranieri Baraglia, Italian National Research Council, Italy
Karolina Baras, University of Madeira - Funchal, Portugal
Stylianos Basagiannis, United Technologies Research Center Ireland -Cork, Ireland
Kashinath Basu, University Wheatley Campus Oxford, U.K.
Mehul Bhatt, University of Bremen, Germany
Rajendra V. Boppana, University of Texas - San Antonio, USA
Nidhal Bouaynaya, University of Arkansas at Little Rock, USA
Samia Bouzefrane, Conservatoire National des Arts et Métiers, France
Tone Bratteteig, University of. Oslo, Norway
Gregor Broll, DOCOMO Euro-Labs, Germany
Beatrice Cahour, National Centre for Scientific Research / Telecom ParisTech - Paris, France
Juan-Carlos Cano, Universitat Politècnica de València, Spain
Serge Chaumette, Bordeaux Computer Science Research Laboratory (LaBRI) - Universiy of Bordeaux, France
Hao Chen, State University of New York at Binghamton, USA
Liming (Luke) Chen, University of Ulster at Jordanstown, UK
Xin Chen, NAVTEQ Research, Nokia - Chicago, USA
Yao-Yi Chiang, University of Southern California, USA
Jacek Chmielewski, Poznan University of Economics, Poland
Jaz Hee-jeong Choi, Institute for Creative Industries and Innovation, Australia
Diane Cook, Washington State University, USA
Yang Cui, Huawei Technologies - Beijing, China
Rodolfo de Paz Alberola, United Technologies Research Center Ireland – Cork, Ireland
Vladimir Deart, Moscow Technical University of Communication and Informatics, Russia
Eugen Dedu, University of Franche-Comté, France
Jerker Delsing, Lulea University of Technology, Sweden
Catello Di Martino, University of Illinois - Urbana Champaign, USA
Michahelles Florian, ETH-Zurich, Switzerland
Ahmed Frikha, Orange, France
Kaori Fujinami, Tokyo University of Agriculture and Technology, Japan

Table of Contents

Wireless Database Searching Scheme Using GSM Modems

Subrata Chatterjee
Department of Electrical Engineering
National Institute of Technical Teachers' Training & Research, Kolkata
E - mail: subrata0507@sify.com

Sumit Kumar Das
Department of Electrical Engineering
National Institute of Technical Teachers' Training & Research, Kolkata
E - mail: sumit.rick@gmail.com

Abstract—**With the development of mobile communication technologies and the popularity of relating devices, GSM network based intelligent systems are being used more and more widely. Most of existing intelligent systems have been built on mobile platforms, but these systems don't provide any facility that can save our energy. Again, the work is not time efficient. But, today, this work needs to be performed from any corner of the world, since people can't afford to visit the field of action every time they want something to be done. In view of this, a wireless database searching scheme has been developed. With a GSM modem as hardware carrier, the system receives information from outsiders, searches in database and sends the result through short messages independently. Basically, it helps to transfer information between the organization (where the system has been implemented) and the external world. Furthermore, receiving any information from an authorized number can also update the database remotely using this system.**

Keywords-Intelligent system; Wireless; Database searching; Authorized number.

I. INTRODUCTION

Wireless data services and systems represent a rapidly growing and advancing segment of the communication industry. While the wireless data industry is becoming increasingly diverse and fragmented, one can identify a few mainstreams, which relate directly to users' requirement for data services [2, 4, 5, 6, 7, 10]. With the widespread deployment of wireless networks and the fast growing popularity of smart mobile devices, there has been an increasing interest in wireless data services from both industrial and academic communities in recent years. Point-to-point access employs a basic client-server model, where the server is responsible for processing a query and returning the result to the client via a dedicated point-to-point channel [3, 9]. For instance, in search of a book, people must go to the library. But, lack of time makes it pretty difficult for a person to go to a library searching for a book, unaware of the fact if it is available or not, and also, if available, how many. It is time consuming because there may be a large queue at the counter. Even though, they can get the conformation via email or phone calls. But, this is not an independent process; it is dependent on the staff and also, it is not instantaneous, they must wait for reply. Therefore, how to improve the mobile information services' efficiency at low cost has become a research hotspot.

The advancement of mobile computing technologies in recent years has contributed to the growth of smart cities. Some thing is to be highlighted here: internet may be indispensable today, but still it is not that friendly for many of the users. On the other hand, nowadays, most of the users know to operate the mobile phones and write messages. For this simplicity, the Global System for Mobile communication (GSM) digital wireless network has been developed. It may be used to transmit data at rates of 9600 bits/s [11]. We can also use a symbian smart phone and install the wireless database viewer plus, but it is costly.

In order to overcome this problem, a wireless database searching scheme has been developed. From anywhere people can get the valuable information about any book in a library. SMS can be sent between users or to and from an application, which gives service development an extra flexibility and encourages innovation [1, 8]. Basically, it interacts between library and external world. It is low cost, user-friendly and convenient for secondary development.

This paper is organized as follows: In Section II, detailed design of the scheme has been presented. This is followed by its experimental results explained in Section III. Discussion is also given in Section IV. Conclusion and future work are given in Section V.

II. DETAILED DESIGN

A. *Functional Module Designs*

The main goal of this scheme is to get useful information about any book wirelessly from a server in the library. A block diagram of this scheme is given in Fig. 1.

The scheme is divided into seven functional modules, and each can provide a different interface and feature implementation.

A GSM module provides a standard serial interface, which has AT commands interface to communicate between a mobile platform and a Data Terminal Equipment (DTE). Therefore, we can use AT commands through serial port to control GSM modem and achieve its receiving and sending short messages.

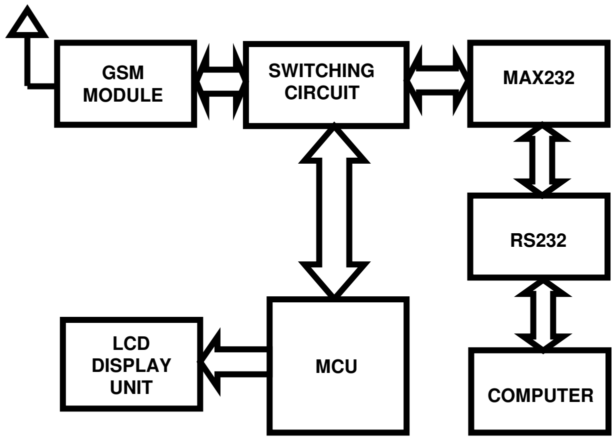

Figure 1. Block diagram of the system.

The switching circuit provides different role to maintain the communication between GSM module and Microcontroller unit (MCU) or MCU and server. Two control pins from MCU are connected to the switching circuit to control the switching functionalities.

MCU (basically ATMEGA32A [12]) is mainly responsible for coding, which controls the total flow of different modules to make other modules manage their own processes. It also maintains two control pins, which are responsible for communication between GSM module and computer. This module extracts the message content and sends to the computer via the switching circuit. Then the module receives result from computer and sends it back to the user through GSM module.

A Computer is used as a search engine, which includes database server and a java application. Database contains specifications of the items (here, books) and its current stock. The application receives query from MCU through RS232 serial port using DB9 female connector, searches in database and sends back the result to the MCU. MAX232 is used to communicate between MCU and RS232 serial port to convert from/to TTL voltage level to/from RS232 voltage levels.

LCD display unit is connected with MCU and shows the status of different data transferring stages.

B. *System Software Architecture Design*

The System software architecture design includes mainly MCU functions and computer functions.

1) MCU Functions

MCU functional diagram is shown in Fig. 2. MCU functions include message content, mobile no. and data & time extraction, check whether the message is received from an authorized mobile number.

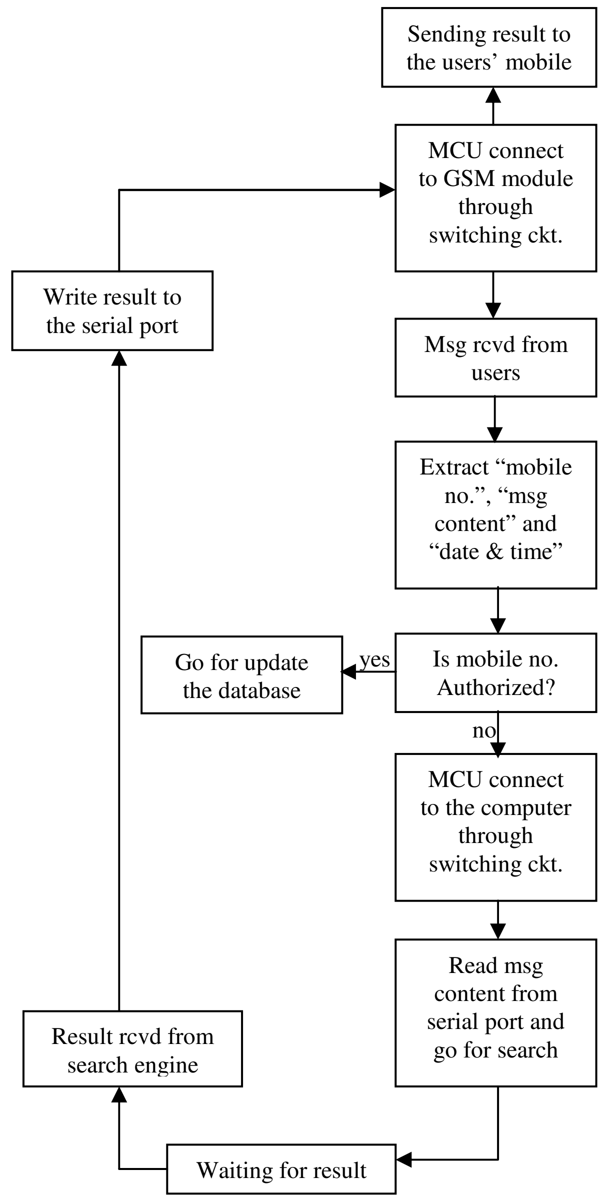

Figure 2. MCU functional diagram

Copyright (c) IARIA, 2013. ISBN: 978-1-61208-282-0

If yes, then go for database updating; otherwise, go for database searching. In case of database searching, at first connects MCU to the computer through switching circuit, then sends the message content to the computer and waiting for the searching result. After receiving the result from the computer, system connects MCU to the GSM module and sends the result to the users' mobile through the GSM module. These functions have been implemented using C programming.

For debugging AVR software the AVR Studio 4 have been used as an Integrated Development Environment. The AVR Studio allows chip simulation and in-circuit emulation for the AVR family of microcontrollers. The AVR Studio uses a COF object file for simulation. This file is created with through the C compiler by selecting COF as the output file type.

2) *Computer Functions*

Computer functions include mainly database searching and updating. Making a database connection has been done already. After reading data through a serial port, searching is to be done and the results to be written to the serial port. These functions have been developed using Java programming.

Basically the JAVA application of the system is always in running condition, when data comes through the serial port, searching will be done by the application and send the result through serial port to the microcontroller. To run JAVA application some system requirements (like JDK 6 from Sun/Oracle and Eclipse IDE for Java Developers) have been installed. We have used RXTX Serial port Library to access serial port with Java. In our Java program we have implemented Serial-Port-Event-Listener and overrode the serial-Event method. Whenever data is coming in serial port, this method is automatically called. For designing the system, we have used Microsoft office access 2007.

C. Operation Process

Using wireless database searching scheme any external user can search for a particular book automatically within a short time period from anywhere. They have to send a message containing the book description from their mobile phone and after some time, they will get information regarding status of that particular book.

Normally, GSM module is connected to the MCU through switching circuit. After receiving any message, MCU extracts mobile number, message content and date & time, and then displays all the data through LCD display unit. Then MCU is connected to the computer through switching circuit. A Java application is always in running condition in the computer system. After reading the message content from the serial port, Java application will search in database and write the result to the serial port. After getting result, MCU will be connected to the GSM module and send back the result to the users' mobile. Using this scheme, authorized person can also update the database remotely.

III. EXPERIMENTAL RESULTS

A. *Experimental setup*

The experimental setup is shown in Fig. 3 and Fig. 4.

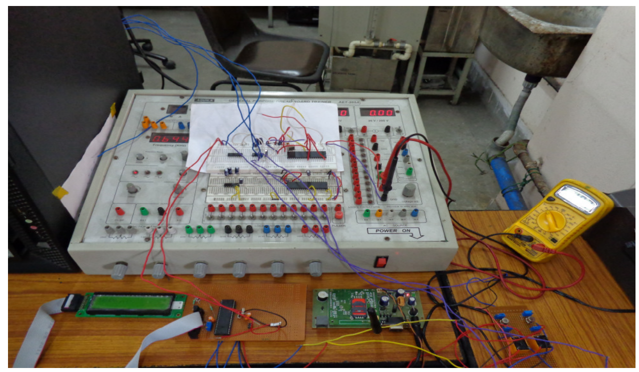

Figure 3. Front view of experimental setup

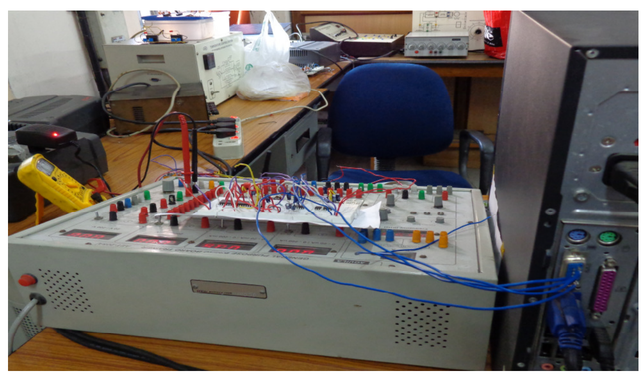

Figure 4. Back view of experimental setup

We have designed a Microsoft Access database as shown in Fig. 5. The book-Details is the Table name and there are some fields (such as title, author, accession-no, copyright, edition and volume). For testing the system, we have included two same title of aa, single title of bb and none title of cc.

After powered on the PC, we have to open Eclipse environment [13] and run that application as Java application as shown in Fig. 6.

 ISBN: 978-1-61208-282-0

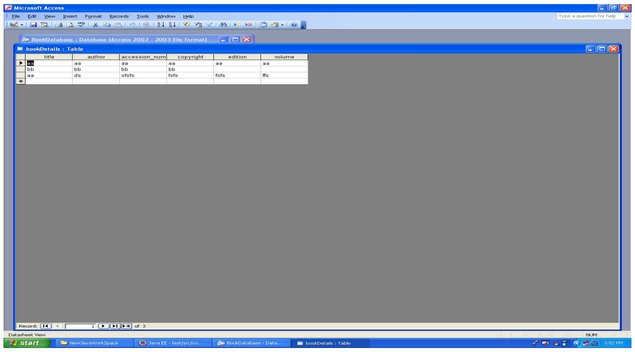

Figure 5. Microsoft Access database

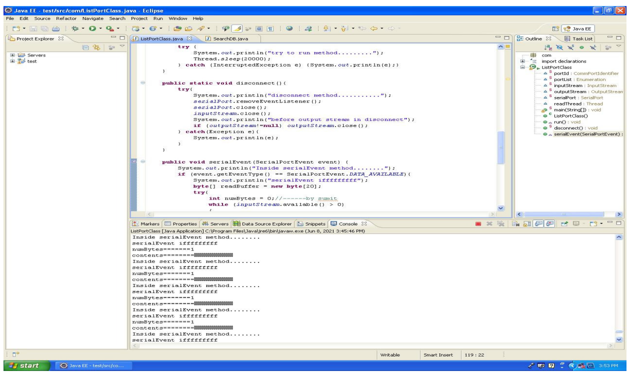

Figure 6. Running Java application

B. Steps for Results

After switching the system on, LCD initialization, baud rate and input-output pins are set up, that are a part of the primary settings. During this time, LCD module displays the message “INITIALIZING…” which is shown in Fig. 7. After completing these tasks, “READY……” is exhibited, this is shown in Fig. 8. Fig. 9 shows the message content, which will be sent to the system. After receiving the message through GSM, the number from which the message has come, message content and message details (like date and time) will be shown in LCD module in Figs. 10 – 12. Then the content is sent to the computer and the status will be shown in Fig. 13. After that, the computer sends the response to the user mobile. The status and useful information received by mobile are shown in Figs. 14 – 15. Similarly, for different status, the computer sends different messages to the user mobile, which are shown in Figs. 16 and 17.

Figure 7. Display after powered on

Figure 8. Display after initializing

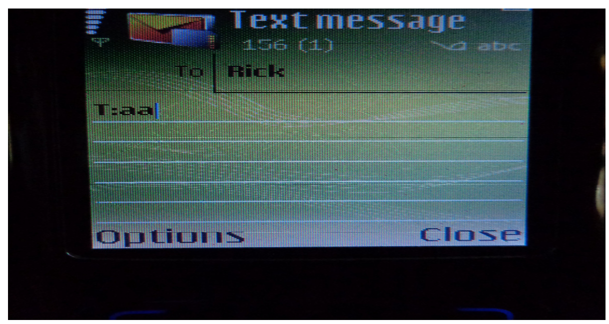

Figure 9. Searching for “aa”

Figure 10. Display the mobile no.

Figure 11. Display the msg content

 ISBN: 978-1-61208-282-0

Figure 12. Display date & time

Figure 13. Data sending to the PC

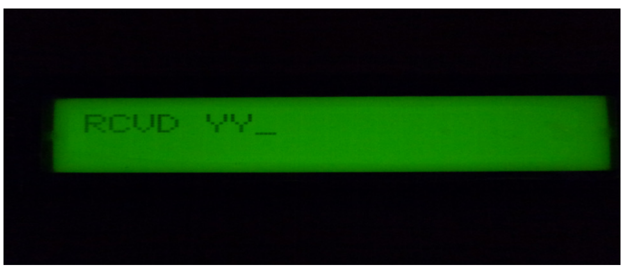

Figure 14. Data received from PC

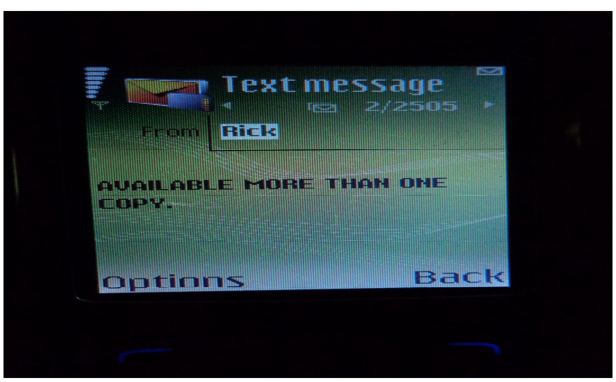

Figure 15. Msg received from the system

Similarly searching for T:bb, we have received “AVAILABLE ONLY ONE COPY”.

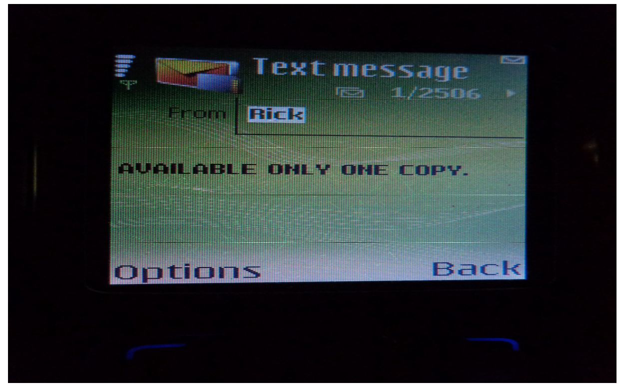

Figure 16. Msg received for “bb”

Searching for T:cc, we have received “CURRENTLY NOT AVAILABLE”.

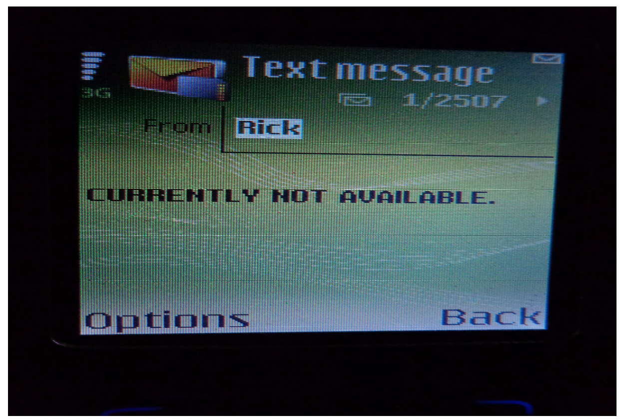

Figure 17. Msg received for “cc”

IV. DISCUSSION

The experimental flow chart is found to have quite good response with the library users’ queries from anywhere. The experimental results are found to have good repeatability. The GSM module of the receiver side finds the transmitter output and the useful information is sent back to the users according to their queries quite satisfactorily. The designed circuit saves energy and valuable time. Another advantage of this system is its individuality. It works automatically after receiving message without any involvement. The material cost of this system is not a big deal for a library and its design is very simple.

When the system is powered on, it should be properly started. Otherwise problem will occur. Character missing out may be occurred. Another thing is to be noticed that after every time powered-on the PC, the software application should be run manually. After that, no need to be taken care about the system.

 ISBN: 978-1-61208-282-0

The design has a good flexibility and can be implemented in different organizations regarding part-searching facility, medical stores, banking sectors and even government sectors. So, people can easily avoid the queue at the counters and save their valuable time and energy. Hence the developed automation system may be treated as low cost reliable and user friendly system.

V. CONCLUSION AND FUTURE WORK

Nowadays, the database is more and more widely used, but the research combining it with message system is still limited. This Database system (DBS) is connected with mobile phone; hence the library user can get useful information rapidly. On the average, it only takes 1-2 minutes (depending upon size of the database and length of the title) to send a message, that is, the DBS has a higher efficiency of delivering the information. From the experimental study, a good reputability has been observed in the proposed system designing. Moreover, the experimental results remain unchanged. The GSM module finds the transmitter (users' mobile) output and the useful information is returned back to the users according to their queries quite satisfactorily. The designed circuit saves energy and valuable time. It works automatically without any involvement. The system can not only strengthen the independency and individuality of people, but also promote people's learning.

There are several scopes for improving on the work presented here. During searching functionality (from receiving message to transmitting message), if the GSM module is receiving any new message, the message will be wasted because at that time microcontroller is being connected to the computer. In future work, a queue can be implemented in the system which stores the new messages and after completion of the current cycle the next message will come from the queue. For "available only one copy" the book cannot be issued. In future work, a system can be implemented, using that we can get a soft-copy of required rare document like journal papers, reference book, etc. (after deposition of required amount of money in bank) through email independently within a short time period. We will study these in the near future.

REFERENCES

[1] S. Younis, "Analysis of Wireless Data Transmission over GSM Short Message Service (GSM-SMS)", http://crystal.uta.edu/~kumar/cse6345/Shehzad_Younis.pdf.

[2] K. Pahlavan, and A. H. Levesque, "Wireless Data Communications", Proceedings of the IEEE, vol. 82, no. 9, September 1994, pp. 1398-1430.

[3] B. Zheng, W. C. Lee, and D. L. Lee, "On Searching Continuous k Nearest Neighbours in Wireless Data Broadcast Systems", IEEE Transactions on Mobile Computing, vol. 6, no. 7, July 2007, pp. 748-761.

[4] N. Wang, "Material Information Management System Design in Enterprise", Proceedings of 2nd International Conference on Computer and Automation Engineering [ICCAE 2010], Feb. 2010, pp. 521-525.

[5] S. Cao, "GSM Modem-based Mobile Auxiliary Learning System" International Conference on Computational Intelligence and Software Engineering [CISE 2009], Dec. 2009, pp. 1-4.

[6] T. Jamil, "Design and Implementation of a Wireless Automatic Meter Reading System" Proceedings of the World Congress on Engineering [WCE 2008], vol. I, July 2008, UK.

[7] R. C. Figueiredo, A. M. O. Riberio, R. Arthur, and E. Conforti, "Remote SMS Instrumentation Supervision and Control Using LabVIEW", pp. 317-342. www.intechopen.com.

[8] A. N. Ansari, A. Navada, S. Agarwal, S. Patil, and B. A. Sonkamble, "Automation of Attendance System using RFID, Biometrics, GSM Modem with .Net Framework", International Conference on Multimedia Technology [ICMT 2011], July 2011, pp. 2976-2979

[9] Q. Hu, D. L. Lee, and W. C. Lee, "Performance Evaluation of a Wireless Hierarchical Data Dissemination System", IEEE International Conference on Mobile Computing and Networking, USA, pp. 163-173.

[10] C. Haifeng, "SQL-based Educational Management System Design", 2nd International Conference on Computer Engineering and Technology [ICCET 2010], April 2010, pp. v3 (441-445).

[11] M. S. Hansen, "Wireless access to a pharmaceutical database: A demonstrator for data driven Wireless Application Protocol applications in medical information processing", J Med Internet Res 2001;3(1):e4.

[12] http://www.alldatasheet.com/datasheet-pdf/pdf/255661/ATMEL/ATMEGA32A.html.

[13] http:/www.eclipse.org/

Business Model Scenarios for an Open Service Platform for Multi-Modal Electric Vehicle Sharing

Uschi Buchinger, Sven Lindmark, Olivier Braet
iMinds-SMIT, Vrije Universiteit Brussel
Brussels, Belgium
e-mail: uschi.buchinger@iminds.be, sven.lindmark@iminds.be, olivier.braet@vub.ac.be

***Abstract*—Triggered by environmental concerns, smart mobility solutions have expanded in recent years. This includes the development of an electric vehicle market, car- and bike sharing concepts and better route planning systems for public transportation. The fusion of these approaches opens the door for new business models for cooperating industries in the field of multi-modal electric mobility. This paper provides a selection of scenarios about how the interplay between mobility- and infrastructure providers can affect their business models. It concludes that the continuous technical and business interactions between multiple partners would profit from the integration of an Open Service Platform that handles data management and coordination tasks for the partners.**

Keywords-Business models; Electric vehicles; Charging infrastructure

I. INTRODUCTION

Triggered by climate change and global resource shortages, the transportation industry faces times of changes. As a consequence, there is an increased industry and policy interest to develop and improve *electric vehicles* (EVs) and make them more commercially viable [1], [2], [3].

But the EV industry is confronted with many challenges of technical, economical, organizational and social nature. Customers are skeptical regarding long charging times, short driving range or the height of initial investments for the vehicles or components such as the rechargeable batteries. The fragmentation of players on the supply side (battery provider, car manufacturer, infrastructure provider, etc.) causes a lack of a single point of sale, which creates additional hurdles for customer adoption [4], [5].

These challenges can be addressed in many ways. Some approaches have arisen in the mobility industry including i) better utilization of vehicle capacity through leasing, sharing and co-using programs [6] and ii) the development of smart *Information and Communication Technology* (ICT) systems. By being able to consult smart technology previous to the journey, wayside and on board (e.g., while driving via roadside information panels), integrated multi-modal traveling and the easy changing of transport systems is facilitated [6], [7].

Kley et al. [8] classify all these emerging trends in the electric mobility sector in three segments: vehicle and battery, infrastructure, and system services (or integration into the energy system).

Earlier studies, such as the EURELECTRIC concept paper [19], and the report on Electric Vehicles in Urban Europe [20] analyzed various market models, key players and B2B cooperation in these segments. Thereby they define the requirements for the expansion of an electric vehicle market. However, there is no research on business model of integrative Open Service Platforms (see below).

New technology (platforms) forms a logical next phase by searching for ways to combining the three segments and thereby supporting networked electric mobility patterns.

In Belgium, a personal card where individual transportation contracts can be stored (called MOBIB card), is one of the pioneers of offering a networked mobility solution. It integrates multiple mobility services. However, MOBIB is not focused on electric mobility [9].

Instead, it is the National Railway Company of Belgium (NMBS/SNCB – *Nationale Maatschappij der Belgische Spoorwegen/Société Nationale des Chemins de fer Belges*) that moved forward by creating an *Open Service Platform* (OSP) where various players from the (electric) mobility industries are linked. This includes amongst others car manufacturers, charging pole providers, energy providers and –distributors or mobility data providers. The platform is operated under the name “Olympus” and provides since 2012, services related to namely the sharing of electric cars, scooters and bicycles in four cities of Flanders. Embedded in a test bed, the project aims at generating insights into the market throughout its operation period of three years [10].

Hence, NMBS/SNCB combines two strategic points that are recommended by Shaheen et al. [11] to stimulate the development of the vehicle sharing industry. These include i) the coordination and linkage of several services from the mobility and non-mobility sectors and ii) the incorporation of superior communication, reservation, and billing technologies [11].

The construction of such an Open Service Platform that enables EV-sharing *and* coordination of shared (public) EV-infrastructure requires an adequate service offer to a wide range of partners from all three segments defined before: vehicle and battery, infrastructure and electricity sector. The task that the Olympus platform performs, namely coordination of *EV-sharing and EV infrastructure sharing*, is here abbreviated by EV-I-sharing. Joining such a network necessitates the restructuring of business models for (so far independent) industries. Various options emerge that might result in the reallocation of control parameters and value creation for the individual partners.

This paper will examine how the business models of existing and new entities in the EV-I-sharing ecosystem could look like. Within this paper, the focus will be on a consumer-oriented approach. The obvious contact points for consumers are either the mobility- or infrastructure sector. Consequently, in this paper, we delimit ourselves from analyzing the electricity or other relevant sectors.

By doing so we will be able to answer the question: How can smart technology enable coordination of existing - and facilitation of new business models in the EV-I-sharing sector in order to provide multi-modal mobility alternatives to end customers.

The paper will use the value network and business model matrix developed by Ballon [12], elaborated in Section II. On the basis of this framework, Section III develops the value network. It will incorporate the actors, tasks or roles and relationships of the mobility and infrastructure sector. It will also introduce the dominant "As-is" business model, i.e., the one operated today by multiple EV-sharing providers and which will serve as a starting point for the introduction of further business model scenarios.

The business models are presented and analyzed in Section IV. In Section V, we compare the different scenarios and give suggestions of their ability of real-life implementation. We end with a conclusion and suggestion for further research in Section VI.

II. METHODOLOGY

In this paper, preceding the description of various business models, the value network of the EV-I-sharing concept will be envisaged. The value network consists of three building blocks: business actors (persons or corporations mobilizing tangible or intangible resources), business roles (business processes fulfilled by one or more actors) and business relationships (the contractual exchanges of products or services for financial payments or other resources; represented through value chains). In this paper, actors are described also as partners.

Based on this generic value network canvas, alternative business model scenarios will be constructed and compared. While there are many business model frameworks proposed in the literature, notably Osterwalder [13] and Chesbrough [14], these are usually more suited for aiding individual firms and less suited for guiding collective innovation processes. It is therefore necessary to consider a stream of research that attempts to provide a more coherent treatment of the most relevant business model parameters while at the same time focusing mainly on the relationships between the stakeholders involved.

Hence, we will follow the framework of Ballon [12], displayed in TABLE I, which defines several parameters upon which business networks can be analyzed. The parameters encompass the value network, the functional architecture and financial model, and value configuration [12], [15].

TABLE I. BUSINESS MODEL MATRIX (SOURCE: [12])

CONTROL PARAMETERS				**VALUE PARAMETERS**			
Value Network Parameters		***Functional Architecture Parameters***		***Financial model Parameters***		***Value Configuration Parameters***	
Combination of Assets		Modularity		Cost (Sharing) Model		Positioning	
Concentrated	Distributed	Modular	Integrated	Concentrated	Distributed	Complement	Substitute
Vertical Integration		Distribution of Intelligence		Revenue Model		User Involvement	
Integrated	Disintegrated	Centralized	Distributed	Direct	Indirect	High	Low
Customer Ownership		Interoperability		Revenue Sharing Model		Intended Value	
Direct	Inter-mediated	Yes	No	Yes	No	Price/Quality	Lock-in

From the given parameters, we chose five upon which the succeeding business models are analyzed. These are the Combination of Assets, Customer Ownership, Distribution of Intelligence, Cost (Sharing) - and Revenue (Sharing) Model.

The five parameters are defined as follows [12]:

Combination of assets is a value network parameter that focuses on the input, usage and combination of resources from all partners.

Customer ownership, also a value network parameter, refers to the relationship with the end customer examining, amongst others, the access to key information of the customer, the type of contact (direct or intermediated), the level of intensity and proximity to the customer.

Distribution of Intelligence belongs to the parameters describing the functional architecture of business networks. In ICT systems, this refers to the distribution of processing power, control and (management of) functionality across the system.

Cost (Sharing) Model and *Revenue (Sharing) Model* are both financial model parameters. The former discusses how costs (investment) for design, development and exploitation of a product or service are shared in the business network. It relates to sunk costs or up-front investment and marginal costs. The latter examines the business model with regard to income streams (direct/indirect) and whether and how revenues are shared. Apart from distribution revenues over several actors, it can also concentrate on one actor.

Considering the information made available by the project partners, these were the parameters on which empirical data could be collected during expert interviews and interactive business modeling workshops. The information gathered during these interactive moments were extended with data gathered from desk research and literature review.

III. EV- AND EV-INFRASTRUCTURE-SHARING

A. Value Network Description

When illustrating the value network of EV-I-sharing, we identified three industrial streams. Each stream focuses on different vertical market segments and consists of the roles that together build the value chains. For the Open Service

Platform (OSP), we distinguished a mobility-, an infrastructure-, and an interactivity- and data stream (Fig.1). Further streams (e.g., electricity) are not considered within the scope of this paper. The value chains of each stream will be divided into three phases: the service development/ creation phase, the service delivery/distribution phase and the service consumption/usage phase.

Firstly, the *mobility stream* comprises the provision of an electric vehicle (e.g., electric cars, bicycles or scooters). In the service delivery phase the "enabling" services precedent to the usage of the EV are placed. They encompass registration of customers, authentication-token provision, reservation of mobility items, billing of customers, clearing tasks and authentication of the token on the spot. The actual usage of the mobility item is the contact point for the customer and is placed in the service usage phase. Roles only describe the task itself, not the specific configuration. For example, "billing" includes all variations and frequency of payment: flat rate fees prior to the usage, during the times of membership (e.g., subscription) or after the usage (e.g., pay-per-use) as well as combinations of these.

Secondly, the *interactivity and data stream* focuses mainly on data gathering and processing and thus represents the application intelligence of a value chain. These data processes actually exist *in* each of the other streams (and even in each role itself). Since this is a layer of intersection, it is however singled out and builds an own stream in this value network. Hence is thus conducted here that data from resources (i.e., vehicles and charging infrastructure equipment), customers and events (i.e., changes in the status of resources) are recorded, aggregated and encoded. Encoded data is edited. Data sharing, extraction, recombination and usage by all business partners happen in the usage phase.

Third, the *infrastructure stream* focuses on EV infrastructure supply, e.g., charging poles and parking facilities. It comprises hardware and software development in the service development phase. Infrastructure deployment/maintenance follows in the service delivery phase. In existing business models of charging pole/parking lot providers, it is not uncommon to have similar procedures in the service delivery phase of the infrastructure stream as in the mobility stream. In public and semi-public parking/charging facilities, EV owners can subscribe for the usage of parking lots/charging poles whereby the parking lot/charging pole providers take care of registration of customers, authentication-token provision, reservation of according items, billing of customers, (clearing tasks in the B2B sector) and authentication of the token on the spot [16].

For simplicity, in our scenarios, the sole initial money flow will come from the customer's EV usage (mobility stream).

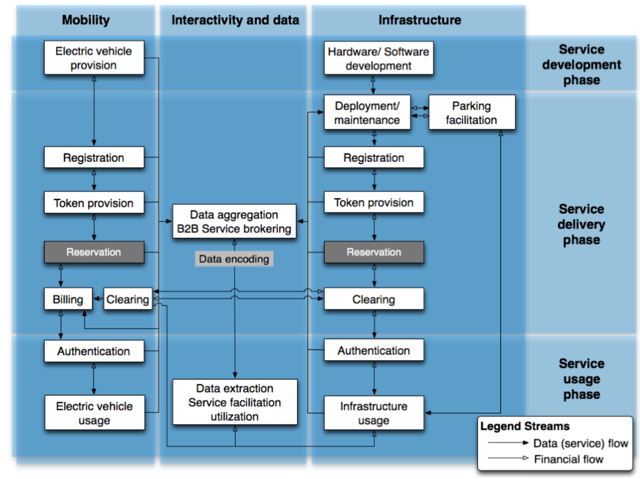

Figure 1. Generic EV- and EV-infrastructure-sharing value network

The costs of the infrastructure provider and other network partners need to be covered by B2B clearing. Data extraction/sharing and infrastructure usage will demand revenue sharing. Along the value chains, data/services flow down (indicated by a filled arrow) while money flows up (indicated by a plain arrow). Fig. 1 illustrates the value network of the EV-I-sharing ecosystem.

In what follows, multiple business models are outlined, mapping various partners, and cooperation between them.

The term 'infrastructure provider' will be used for a charging pole/parking lot provider and the term 'infrastructure' for charging/parking spots.

B. *"As-is" business model*

The initial model is applicable to existing EV-sharing concepts (see for example Autolib' [17] or Zen Car [18]) Tasks of the mobility stream are operated by the mobility provider who registers its own customers, provides a token or access code for the vehicle, handles the reservation process, bills the customers and enables authentication at the resources to unlock/start the vehicle. In this scenario, only the development of infrastructure hardware and software components is outsourced. The mobility provider deploys, manages and maintains acquired charging and parking infrastructure. The execution of enabling services for the infrastructure usage is taken care of by the corresponding ones of the mobility item usage. Data is aggregated in house limited to the mobility provider's data aggregation system.

For the customer, the procedures of the service delivery phase need revision for each new mobility provider with whom he/she signs a contract. The customer needs to register separately for each mobility provider and can charge the vehicles solely at the declared charging facilities. Fig. 2 illustrates the "As-is" business model. The grey boxes indicate the partners who conduct roles. They consist of the mobility provider, infrastructure provider and customer.

 ISBN: 978-1-61208-282-0

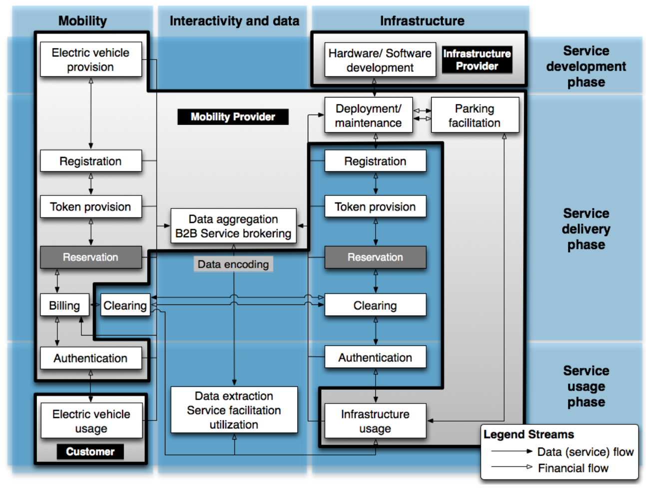

Figure 2. 'As-is' business model

The "As-is" business model construe the chosen parameters:

Combination of assets: The mobility provider integrates all relevant assets for the EV-I-sharing process. It buys or licenses charging equipment and parking facilities. Due to the conjunction of vehicles and infrastructure, services in the delivery phase ('enabling services') need to be conducted only once. Assets are concentrated.

Customer ownership: Solely the mobility provider has customer ownership.

Distribution of intelligence: Intelligence is concentrated at the mobility provider.

Cost sharing model: There is no cost-sharing model, all (up-front) investment and operating costs are borne by the mobility provider.

Revenue (sharing) model: No revenue sharing model is necessary in the single operator scenario; revenues are concentrated with a single actor.

IV. BUSINESS MODEL SCENARIOS

The previous section introduced the value network of the EV-I-sharing concept and the established business model of mobility providers.

Taking into account the high of investment and potential risk for each market entrant, business partners might look for cooperation and joint ventures with other partners in the electric mobility sector. Given the possibilities that emerge from the development of smart ICT, this is becoming more and more feasible. We will therefore introduce three business model scenarios where various players are included, namely mobility providers (including, e.g., EV-sharing or -leasing companies), infrastructure providers (parking spot and charging pole providers), the Open Service Platform (OSP) and the customer. The scenarios were selected because of their potential to illustrate sufficiently contrasting industrial options and their coverage of many aspects in the EV-I-sharing scheme.

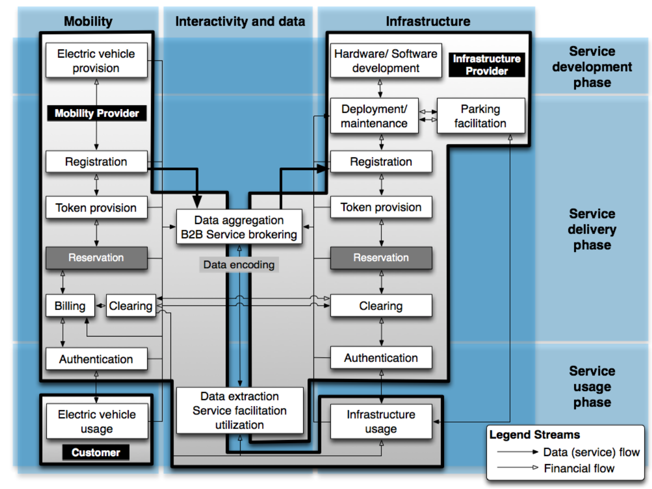

Figure 3. Independent Partner Scenario

A. Independent Partner Scenario

This scenario assumes that the mobility provider facilitates the usage of other public or semi-public charging/parking spots; other than the own (home) charging/parking spots.

The Independent Partner Scenario illustrated in Fig. 3, shows the setup where two companies (mobility- and infrastructure provider) cooperate, but independently execute the roles of the own value chain. No OSP is included.

The data of a registering customer is automatically or on-demand (if the customer explicitly asks for the service) forwarded to the infrastructure provider. After registering the customer in the own database, the infrastructure provider issues a separate token, enables the customer access to the reservation process (if existent), and facilitates the authentication at the charging pole.

Combination of assets: Resources as well as applications necessary to fulfill the 'enabling services' in the service delivery phase are properties of either the mobility provider or infrastructure provider. Each partner aggregates data of resources and events (changing in the status of resources) separately in its system. Only the mobility provider aggregates customer data.

Customer ownership: In this scenario, both partners have customer ownership (the infrastructure provider, e.g., through the provision of the authentication token). The difference is in the billing process; the mobility partner includes this role exclusively in its customer relationship.

Distribution of intelligence: Both partners have their own system of managing the roles along the value chains: their data aggregation pools, processing power and control. Intelligence is distributed in the value network.

Cost sharing model: Each partner is itself responsible for (up-front) investment in design, development and exploitation of products and services that are used in the network. Investments are therefore distributed over various partners.

Revenue (sharing) model: Only the mobility provider is in the position of billing the customer. In the business cooperation, some form of clearing (i.e., revenue sharing) will be necessary to pay the usage of charging poles/parking spots. It is due to bilateral agreements.

While this scenario is suitable for two partners, the more EV-I-sharing industries join the network, the more complex it will become to handle business relationships through bilateral agreements. The complexity rises also for the customer who gets multiple access tokens for EVs and EV-infrastructure. For example he/she might need to swipe a card over a reader for opening a car (provided by the mobility provider) and a different one for stopping the charging process and unplugging the car from the energy system (provided by the infrastructure provider).

B. *Intervening Partner Scenario*

The following variation of the partner model shows how one partner can expand its roles by taking over partner roles in the service delivery phase, as portrayed in Fig. 4. The scenario illustrates the provision of a shared token, meaning that one token of the mobility provider gives access to all infrastructure resources. This actor steers the authentication at the resources.

At the same time the scenario shows a possible way of how the OSP fits in the value network and how it can possibly take over a role in one of the value chains, namely the “registration” of customers for the infrastructure providers. A probable use case should describe this: if a customer registers at the mobility provider the OSP enables that he/she is automatically registered for infrastructure providers’ services.

Second, the OSP collects and passes on all event data in the network. When a vehicle is reserved at the mobility provider, the OSP can coordinate with all infrastructure providers of where and when the vehicle is reserved, what the battery status needs to be, where the vehicle can be plugged at the final destination, etc.

Its main role however is to aggregate events or changes in the status of resources. The OSP collects information about the exact times of the usage of services and resources and acts as a trusted party in the clearing process.

Combination of Assets: The assets are spread between the partners in the system. Whereas the mobility provider (and partly the infrastructure provider) has leading parts, the OSP is mainly a supporting partner.

The mobility provider, apart from allocating resources, has a system for registering new customers. The OSP then collects this data from the initial registering partner (mobility provider) and registers the new customer for partner services. The requirements to make a positive new registration of a customer at a partner service might be more demanding however than the data that is provided by the initial registering actor (e.g., more sophisticated data needed or other registration forms in place). This problem needs to be solved by arrangements between the partners.

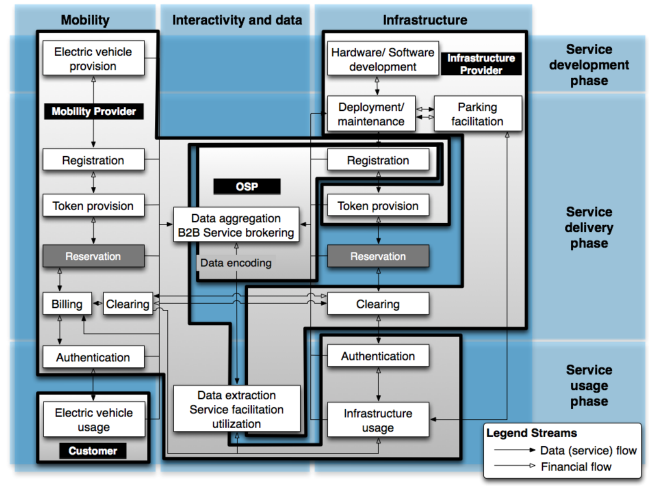

Figure 4. Intervening Partner Scenario

Customer Ownership: The takeover of the registration process of new customers comes with the power over customer data and its processing and forwarding responsibly. In this scenario, solely the mobility provider has direct customer ownership. However, the OSP aggregates customer- and token data collected from all partners.

Distribution of intelligence: Intelligent poles are placed at two edges: the mobility provider that takes over token provision for multiple partners and the OSP that registers customers at partner services. Additionally the OSP collects data of events taking place in the network. By ceding roles to other partners, the infrastructure provider cedes a certain amount of control over certain processes within its value chain.

Cost sharing model: The mobility provider expands its systems in terms of opening token provision system as well as implementing the authentication system backend and on the spot. It might require a large up-front investment. The OSP at the same time needs to invest in a registration system that meets all partner-requirements. Infrastructure providers save costs by not having to develop and maintain customer databases and authentication mechanisms.

Revenue (sharing) model: The income from the usage of the vehicles has to cover the expenses of the infrastructure provider (through bilateral billing agreements) and the Open Service Platform. The mobility provider is the single contact point for the customer; a revenue sharing model must be set up.

Having only two partners in the scenario, an OSP might not be necessary. However, the more partners the ecosystem includes on both sides of the value network, the more complex the scheme with bilateral agreements gets, and the higher the value of a regulatory, coordinating system. When workload and coordination tasks are growing, the OSP can be consulted either for sole data pooling or for fulfilling roles itself.

 ISBN: 978-1-61208-282-0

C. Open Service Platform Scenario

The OSP scenario (Fig. 5) shows a model where the OSP is responsible for fulfilling all roles of all partners in the service delivery phase. This is possible due to data exchange between the partners for customers and resources. All data about customers and infrastructure resources (e.g., location, type, availability) is aggregated in the OSP. The business model is depicted on the value network canvas in Fig. 5.

Combination of assets: This model illustrates the centralization of most assets at the OSP. The OSP has to construct (administrative) systems, processes and mechanisms that cover all requirements of the ‘enabling services’ for both mobility- and infrastructure provider. This raises many challenges. It might be that the applicant is only interested in one or more services of the network but not all that are offered (e.g., only electric bike sharing). It might be that he/she is not entitled to use multiple services (e.g., no driving license). This selection must result in an adjusted registration and invoicing of the customer. The data needs to be reflected on the authentication token. The right modules need to be loaded on the tokens - modules that describe which services are available to the token holder. If he/she subscribed for electric bike sharing, the token shall not give access to, e.g., electric cars.

The mobility provider solely provides EVs. The infrastructure provider is responsible for development, deployment and maintenance of charging poles/parking lots. All other tasks are outsourced to the OSP.

Customer ownership: Neither the mobility- nor the infrastructure provider have direct customer ownership. For the customer, the Open Service Platform appears as the sole service provider.

This can be seen as a form of indirect customer ownership. Registration of new customers is done for all partners in the network that can encompass multiple mobility- and infrastructure providers. Tokens are handed out by the OSP and are valid for all resources. Data from all roles are aggregated by the OSP and can be extracted and used by the partners in the network. Billing of customers and clearing between the partners in the network is conducted by the OSP based on self-generated data. This scenario aims at a single-access-point strategy towards the customer.

Distribution of intelligence: The scenario shows a strongly centralized intelligence in the system architecture. By the aggregation of data, the OSP is competent to control and process most events in the system.

Cost sharing model: The OSP invests in the platform solution for EV-I-sharing concepts regarding customer and infrastructure resource management. Mobility- and infrastructure provider need only to invest in and provide the respective resources.

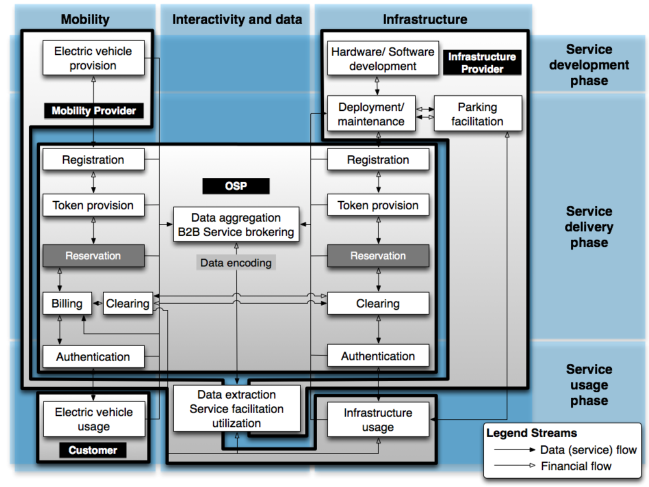

Figure 5. Open Service Platform Scenario

Revenue (sharing) model: Payment for the vehicle usage flows to the OSP instead of the actual service developer (indirect revenue flow). A revenue sharing model must be implemented between the partners.

In this scenario, the OSP is not exclusively a B2B service enabling factor, but an entity in direct contact with the customer. For the mobility- and infrastructure providers, joining such network structure makes them dependent on the performance of the platform. The mobility- and infrastructure providers have no control over systems, processes and mechanism of the customer relationship. For this matter, as for the questions of clearing, a strong and trusted partnership and a high level of transparency are necessary. It is unlikely that partners agree to such a structure where they have only a minimum of control. It needs to be stated however that this represents an extreme scenario and less extreme variations are possible. Nevertheless, from joining such a centrally controlled network, partners profit from the opening of service to a broad customer base and thus a potentially higher usage.

V. Business Scenario Comparison

In TABLE II, a contrasting comparison of the different models that were presented in Section IV is given, rated on the five Business model parameters. Some additional dimensions that emerged in the analytical process are included and rated at the end of the table. They can be mainly affiliated to a dominant parameter that indicates their probability and value in the network. This is expressed with plus and minus.

First it is the *suitability of integrating more partners* in the network. This mainly depends on the openness of the network and the intelligence of the system. The integration of the OSP is an indicator that systems are open and thus capable to integrate and coordinate multiple network partners and their technical standards. Contrary, if system intelligence is centralized either at a mobility- or infrastructure provider, new entrants will likely have to adapt and synchronize their systems. This can be an entrance barrier.

Copyright (c) IARIA, 2013. ISBN: 978-1-61208-282-0

Independency of partners refers to the range of roles and level of vertical integration one partner has to cede to other network partners. The more roles are taken over by one entity the more dependent are the others on its performance.

Ease/Simplicity for customers rates the level of difficulty for the customer to understand the service infrastructure and his/her possibilities of how and what to use it for. Issuing multiple access tokens decreases for example the usability contrary to using one access token for all resources. This applies for all service deliveries towards the customer. The more partners have direct customer ownership, the higher the level of complexity.

Service offer towards customers rates the options for the customer for each scenario. The more partners that are (or can easily be integrated) in the network, the bigger the range of service options for the customer.

VI. Conclusions and Recommendations

This paper illustrated the value network and various possible business models for EV-sharing and coordination of shared EV infrastructure. On a generic value network canvas, four business model scenarios were illustrated that describe possible variations of the interplay between the partners with the focus on mobility- and infrastructure providers.

For each scenario we analysed the impact on five different business model parameters: Combination of Assets, Customer Ownership, Distribution of Intelligence, Cost (Sharing) Model and Revenue (Sharing) Model. Additionally each concept was analyzed upon the suitability of integrating more partners, independency of partners, ease/simplicity for customers and service offer towards customers.

Following the comparison of the scenarios, we conclude that the more partners in the network that conduct the same roles for EV-sharing and the coordination of infrastructure, the larger the need for an central intelligence system. A coordinating Open Service Platform can therefore be integrated either as a pure data hub or as a partner that takes over roles itself in the value network. Dependent on the level of control the partners are willing to cede and the perceived value coming with this, an OSP scheme is feasible that has the power to establish a smart sharing network, open enough to include further players from the sector. The authors infer that the more partners are to be coordinated in the network, the higher the incentives to have a centralized intelligence and data exchange system – thus an OSP.

In conclusion, this paper serves as an approach of how mobility and infrastructure provider can coordinate services to enable a united, attractive multi-modal mobility offer to the customer.

Further research is required when it comes to the implementation of additional value streams, as for example, the electricity sector as well as the outlining of further business model scenarios. Such research should include also investigations into the acceptance and usage of such EV-I-sharing concept by the end-user. Second the aspect of handling data is a topic for further research. It needs to be stated that the OSP scheme requires the implementation of data protection- and security standards. Appropriate measures need to be implemented in the intelligence system. It is thus a question of further analysis of who can implement adequate technical systems to guarantee these standards and which requirements these standards have to fulfill.

Acknowledgment

Olympus is a R&D (Research and Development) project

TABLE II. Business Model Comparison

	Business Model			
	Mobility Provider Scenario	***Independent Partner Scenario***	***Intervening Partner Scenario***	***OSP Scenario***
Combination of Assets	Concentrated (MP[a.])	Distributed	Distributed	Distributed
Customer Ownership	Direct	Direct for both partners	Intermediated, only MP has direct customer ownership	Intermediated, only OSP has direct customer ownership
Distribution of Intelligence	Centralised at the MP, single system	Distributed, two separate systems	Distributed, tendency of centralization at OSP	Centralized (OSP)
Cost (Sharing) Model	Concentrated, all investment from the MP	Distributed	Distributed, investments mainly MP and OSP	Distributed
Revenue (Sharing) Model	Direct revenue flow to MP, no revenue sharing	Direct revenue flow to MP, sharing with IP	Direct revenue flow to the MP, sharing with IP and OSP	Indirect revenue flow to OSP, sharing with MP and IP
Suitability of integrating more partners	N/A	-	+	++
Independency of partners	++	++	+	-
Ease/Simplicity for Customer	++	+	+	+
Service Offer towards Customer	+	+	+	++

a. MP = Mobility Provider, IP = Infrastructure Provider, OSP = Open Service Platform, C = Customer

cofunded by IWT (Agentschap voor Innovatie door Wetenschap en Technologie), the government agency for innovation by science and technology founded by the Flemish Government. Companies and organizations involved in the project are NMBS/SNCB-Holding, Blue-mobility, Infrabel, Optimobil Vlaanderen, Recticel, Green City Tours, Stad Gent, Stad Hasselt, Stad Leuven, Stad Antwerpen, Vlaams Instituut voor Mobiliteit, Transport & Mobility Leuven, Universiteit Gent, Vrije Universiteit Brussel and Katholieke Universiteit Leuven.

REFERENCES

[1] European Commission, “The EU climate and energy package," Climate Action, 2012. [Online]. Available: www.ec.europa.eu/clima/policies/package/index_en.html. [Accessed: 19-Dec-2012].

[2] European Commission. Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009.

[3] J. Addison, “Top 10 electric car makers,” Clean Fleet Report, 2010. [Online]. Available: http://www.cleanfleetreport.com/top-electric-cars-2010/. [Accessed: 08-Jan-2013].

[4] R. Graham, “Comparing the benefits and impacts of hybrid electric vehicle options,” Electric Power Research Institute (EPRI), Palo Alto, CA: 2001. 1000349.

[5] F. Kley, M. Wietschel, and D. Dallinger, “Evaluation of European electric vehicle support schemes,” in Paving the Road to Sustainable Transport, 1st ed., Oxon: Routledge, 2012, pp. 75–95.

[6] S. G. Stradling, M. L. Meadows, and S. Beatty, “Helping drivers out of their cars. Integrating transport policy and social psychology for sustainable change,” in Transport Policy, vol. 7, no. 3, Jul. 2000, pp. 207–215.

[7] J. W. Grotenhuis, B. W. Wiegmans, and P. Rietveld, “The desired quality of integrated multimodal travel information in public transport: Customer needs for time and effort savings,” Transport Policy, vol. 14, no. 1, 2007, pp. 27–38.

[8] F. Kley, C. Lerch, and D. Dallinger, “New business models for electric cars - A holistic approach,” Energy Policy, vol. 39, no. 6, 2011, pp. 3392–3403.

[9] MOBIB, “MOBIB, a world of advantages,” MIVB/STIB. Your journey, 2007. [Online]. Available: www.stib.be/mobib.html?l=en. [Accessed: 11-Jan-2013].

[10] SNCB-Holding, “Olympus” Projects. [Online]. Available: http://www.b-holding.be/fr/projets/olympus. [Accessed: 09-Jan-2013].

[11] S. Shaheen and A. Cohen, “Growth in worldwide carsharing: An international comparison,” Transportation Research Record: Journal of the Transportation Research Board, vol. 1992, no. 1, Jan. 2007, pp. 81–89.

[12] P. Ballon, “Business modelling revisited: the configuration of control and value,” Info, vol. 9, no. 5, 2007, pp. 6–19.

[13] A. Osterwalder, “The business model ontology: a proposition in a design science approach,” HEC Lausanne, 2004.

[14] H. W. Chesbrough "Open Business Models: How to thrive in the new innovation landscape," Boston, Massachusetts: Harvard Business Press, 2006.

[15] E. Faber, P. Ballon, H. Bouwman, T. Haaker, O. Rietkerk, and M. Steen, “Designing business models for mobile ICT services,” in Workshop on concepts, metrics & visualization, at the 16th Bled Electronic Commerce Conference eTransformation, Slovenia, 2003, pp. 9–11.

[16] Servipark, “Servipark,” [Online]. Available: http://www.servipark.com/be/Default.aspx?culture=en-GB. [Accessed: 10-Aug-2012].

[17] Autolib’, “Autolib’," [Online]. Available: https://www.autolib.eu/economy/. [Accessed: 10-Aug-2012].

[18] Zen Car, “Zen Car: The electric solution of car-sharing in Brussels,” 2011. [Online]. Available: http://www.zencar.eu/en/about_concept.cfm. [Accessed: 10-Aug-2012].

[19] EURELECTRIC, "Market Models for the Roll-Out of Electric Vehicle Public Charging Infrastructure. A EURELECTRIC concept paper," Brussels: The Union of the Electricity Industry, 2010.

[20] O. Rodrigues, "EVUE: Electric Vehicles in Urban Europe," Lisbon: URBACT, 2012

A Triple Interfaces Secure Token -TIST- for Identity and Access Control in the Internet Of Things

Pascal Urien
Telecom ParisTech
23 avenue d'Italie, 75013 Paris, France
Pascal.Urien@telecom-paristech.fr

Michel Betirac
EtherTrust, Avenue Louis Philibert
Domaine Petit Arbois 13100 Aix en Provence
Michel.Betirac@EtherTrust.com

Abstract— **This paper introduces an innovative technology based on secure microcontrollers, such as smartcards, equipped with TLS stack. The secure microcontroller, identified by its X509 certificate, is embedded in a triple interfaces secure token (the *TIST*), supporting USB, NFC and Mifare connectivity. The *TIST* secures OPENID and electronic key delivery services and makes them available for multiple terminals such as mobiles, laptops or tablets.**

Keywords- Security, smartcard, NFC, OPENID, TLS

I. INTRODUCTION

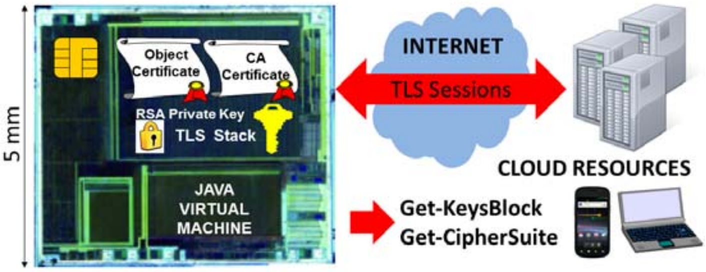

Figure 1. A TLS Stack for Secure Microcontroller

The Internet Of Things (IoT) is an architecture in which billions of devices with computing capacities and communication interfaces are connected to the internet and perform collaborative tasks [4]. In this context security is a major issue. In this paper we focus on access control services to logical (OPENID) and physical (electronic key delivery) resources, which are deployed in laptops, tablets, mobiles or embedded systems such as electronic locks. In previous works [1][2] we introduced a TLS stack with a small memory footprint of about 20 KB, which works in most of the secure microcontrollers of the market such as smartcards (defined by the ISO 7816 standards). The TLS protocol (RFC 2246) is the cornerstone of the internet security; the server is usually identified by its X509 certificate; the client is optionally authenticated with a certificate. Our TLS stack always works with certificates for both client and server, and therefore performs strong mutual authentication, based on PKI, between these entities. Secure microcontrollers [7] (see figure 1) are tamper resistant devices whose security is enforced by multiple hardware and software countermeasures; they include CPU (8, 16, 32 bits), nonvolatile memory (about 100 KB), ROM (about 200 KB) and RAM (about 10 KB). Most of them comprise a java virtual machine (JVM), and therefore run software written in javacard (a subset of the java language) such our TLS stack. As a consequence an object equipped with a secure microcontroller running a TLS stack (see figure 1), performs strong mutual authentication with internet server, and afterward establishes secure channel (i.e. the TLS Record Layer) with cloud computing services. In this paper we describe the integration of this TLS stack in a token that offers three communication interfaces: USB for laptops, NFC (Near Field Communication) for mobile phones, and ISO 14443A (MIFARE) for physical access control.

This paper is constructed according to the following outline. Section 2 introduces the Triple Interfaces Secure Token (or ***TIST***) architecture, and details some services such as OPENID (http://openid.net) authentication and electronic keys delivery [5] available for mobiles phones and laptops. Section 3 describes the concept of dual NFC interfaces, and the logical architecture of applications dealing with this concept. Section 4 details the services supported by the TLS stack embedded in the TIST. Section 5 presents the APIs dedicated to the TIST, available for laptops and smartphones environments. Finally section 6 concludes this paper.

This work was funded by the FEDER *OnDemand* project.

II. TRIPLE INTERFACES SECURE TOKEN - TIST

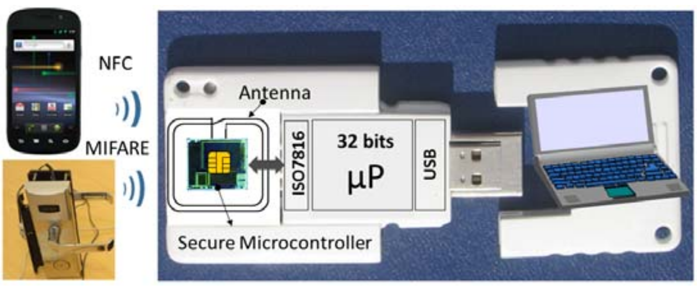

Figure 2. Triple Interface Secure Token (TIST) hardware architecture

The ***TIST*** architecture is depicted by figure 1, it comprises four main components

- The system core is a 32 bits microprocessor, which drives an USB port and an ISO7816 serial interface with the secure microcontroller (i.e. a smartcard)

- The USB port gives access to the smartcard, which usually exchanges packets with the terminal thanks to the well-known PC/SC API.

- The ISO 7816 interface is used for the contact mode, i.e. when the key is plugged to an USB terminal. It transports messages to/from the smartcard, over the ISO 7816 serial link.

- The secure microcontroller (see figure 1) is a smartcard equipped with two communication protocols, first is used in contact mode according to the ISO 7816 standards, and second in contactless mode. In this last case the chip is feed by an electromagnetic field at the frequency of 13,56 MHz; radio packets are exchanged according to the ISO14443 specifications, which have been endorsed by the NFC consortium (http://www.nfc-forum.org).

The TLS stack delivers two main facilities. First it established TLS sessions with remote TLS servers, via the EAP-TLS protocol (RFC 5216) that transports TLS without TCP/IP flavors. The session is transferred to the application (handling the secure microcontroller) upon the reception of the server finished message for TLS full mode, and after the transmission of the client finished message for the resume mode. The session transfer requires two parameters a set of ephemeral keys (the *KeysBlock*) and the associated cryptographic algorithms (the *CipherSuite*). According to a mechanism called container [5], the terminal may push data (such as keys values used by electronic locks) that are ciphered with the secure microcontroller public key (found in its certificate) and signed by a trusted authority. Containers are checked and decrypted by the secure microcontroller.

In summary the two services of TLS stack are first TLS session booting and second container delivery. The following sections presents applications based on these facilities such as OPENID [3][8] and key delivery [5][6], which are available with three communication interfaces, i.e. NFC, Mifare, and USB.

A. NFC Interface

The NFC technology covers an umbrella of standards working with the 13,56 MHz frequency, with throughput ranging from 106 Kbits/s to 424 Kbits/s. Android is an operating system originally created by the Android Inc company, bought in 2005 by Google. The gingerbread version (v2.3) endorses the NFC technology; more precisely the mobile may be used as a NFC reader that communicates with external NFC devices feed by its electromagnetic field.

When the ***TIST*** is tapped against the mobile, an Android application registered to the NFC service is started (see [5] for more details). This application realizes four main functionalities:

- It exchanges packets with the TLS stack running in the secure microcontroller;

- It boots the TLS session and transfers its control back to the mobile (via the *Get-KeysBlock* and *Get-CipherSuite* commands)

- It manages TCP/IP sockets resources, and realizes a proxy server in order to establish the logical glue between the browser, the external contactless smartcard and the remote internet server.

- It pushes toward the NFC device, container received over HTTPS session.

OPENID is a typical application for NFC services for mobile in which the embedded TLS stack is used for mutual authentication with the OPENID server (see [5][8] for more details).

B. Mifare Interface

Mifare devices introduced in 1994 by the NXP Company are very widely deployed for access control purposes, used by transport infrastructures or electronic locks. For example the *“Mifare Classic S50”* component is organized in sectors, divided in 16 bytes blocks, whose reading and writing operations are controlled by a couple of 48 bits keys (*KeyA* and *KeyB*). Our contactless smartcard provides Mifare emulation, and therefore is compatible with the Mifare ecosystem. Furthermore the secure microcontroller has access to Mifare blocks. As we demonstrated in [6] this feature enables the secure delivery of keys, transported in containers. TLS sessions with internet keys servers are booted from the secure microcontroller. The user experience is quite simple: the user taps the ***TIST*** against its mobile, starts the Android application that collects a key which is afterwards stored in the appropriate Mifare block.

C. USB Interface

The USB interface provides connectivity for laptops. The ***TIST*** is accessed via the PC/SC API which is supported by Windows and Linux operating systems. It works as a smartcard reader to which is internally plugged the secure microcontroller. A proxy server application (see section 2-A) establishes the logical glue between the PC browser, the secure microcontroller and a remote internet server. This architecture was previously detailed in [2], and is used for OPENID platform secured by EAP-TLS smartcard [1] It should be noticed that the key delivery service described in section 2-B is also provided for laptops.

III. ABOUT DUAL NFC INTERFACES APLLICATIONS

The ISO 14443A standard specifies the boot sequence of a NFC device, when it is feed by the electromagnetic field (whose frequency is 13,56 Mhz) generated by a NFC reader, providing a throughput of 106 Kbits/s. The reader uses an ASK 100% modulation with for packet transmission, and a subcarrier of 848 kHz for data reception. The booting process is illustrated by the figure 3,

Initially the card powered by the RF field is in the IDDLE state. The reader sends a REQA (Request Command of Type A) packet and waits for an ATQA (Answer To Request of Type A) message, whose two bytes content indicates the protocol to be used for the anti-collision process. Afterwards the reader performs an anti-collision loop (based on SELECT and ANTICOLLISION commands) whose goal is to collect the UID (Unique Identifier), attribute (4, 7 or 10 bytes). The anti-collision procedure ends by a SAK packet (SELECT Acknowledge), which indicates if the card works with the ISO7816-4 protocol or with the MIFARE protocol. If the card is ISO7816-4 compliant the reader sends the RATS (Request for Answer To Select), which is acknowledged by an ATS (Answer To Select); otherwise the reader and the card exchange MIFARE messages.

The availability of both MIFARE and ISO7816-4 protocols is usually referred as a dual NFC interface. Despite the fact that MIFARE protocols are proprietary (i.e. designed by the NXP company), they are widely used for access control and transport (about 70% of the transport market).

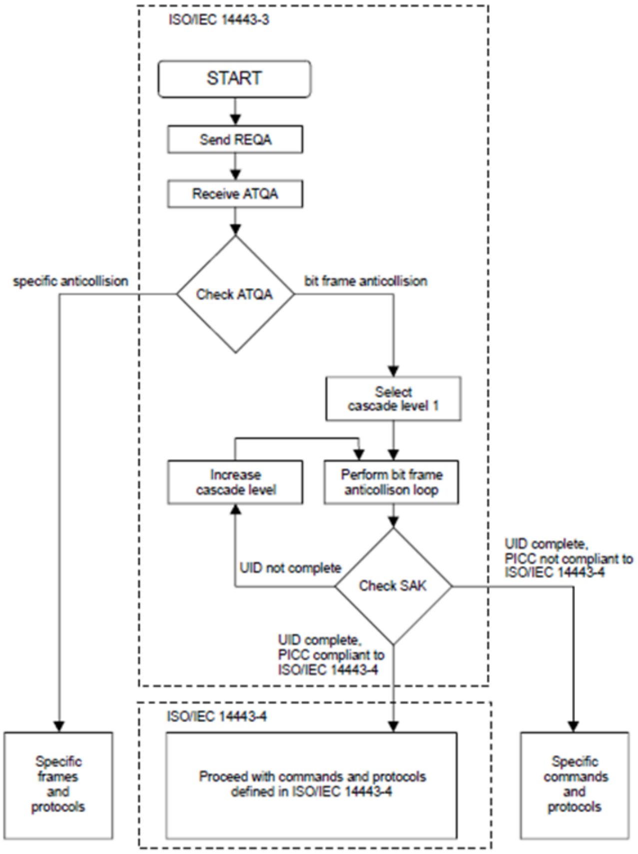

Figure 3. The ISO14443-A state machine (from the ISO14443 standard)

The ISO7816-4 standard provides a communication interface both for contactless (NFC) and contact smartcards that usually comprise a java virtual machine (JVM) and therefore run programs written in the JAVACARD language (a subset of JAVA).

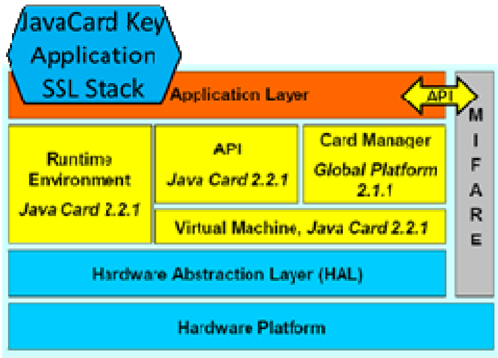

Figure 4. Illustration of a dual interfaces apllication

The JCOP operating system, designed by the IBM company and afterwards bought by the NXP company supports a JAVACARD API (*JZSystem.readWriteMifare*) that enables read and write operations in MIFARE blocks from a JAVACARD application.

The Java Card Forum (JCF) API supports since the JC2.2 release a dedicated class (*javacardx.external.Memory*) providing access to memory subsystems such as MIFARE.

The figure 4 illustrates the architecture of an electronic key service dedicated to legacy MIFARE lock readers. A TLS-Stack running in the javacard is used to securely transfer a key value from a WEB server. This attribute is afterwards written in the MIFARE memory.

IV. THE TLS APLLICATION

	CLA	INS	P1	P2	P3	LE
Select	00	A4	04	00	LC bytes	0 byte
Verify PIN	00/A0	20	00	00 or 01	LC bytes	0 byte
Set Identity	00/A0	16	80	00	LC bytes	0 byte
Reset	00/A0	19	10	00	0	0 byte
Process EAP	00/A0	80	0.last 1.more	00	LC bytes	LE bytes
Get CipherSuite	00/A0	82	CC	00	LE=0x03 or 0x24	0x40
Get KeyBlock	00/A0	82	CA	00	LE=0x40 or 00	0x40
Get Result	00/A0	C0	00	00	LE	#0
Fetch Result	00/A0	12	00	00	LE	#0
Write Container	00/A0	D0	0.first 1.more 2.last	00	LC bytes	0 byte

Figure 5. ISO7816-4 Interfcae for theEAP-TLS smartcard

The TLS embedded application is based on the EAP-TLS smartcard IETF draft specification [1]. The software interface is made of ten (Select, Verify-PIN, Set-Identity, Reset, Process-EAP, Get-CipherSuite, Get-KeyBlock, Get-

Result, Fetch-Result, Write-Container) ISO7816-4 commands, illustrated by figure 5.

Select activates the EAP-TLS application, which is according to the ISO7816 standard identified by a 16 bytes number, the AID (application identifier).

Verify-PIN unlocks the application; two PINs are available one for the user and the other for the administrator, which are associated to different privileges. The administrator manages all the application resources.

Set-Identity binds TLS sessions to a set of cryptographic credentials that form the user's identity. An identity is a set of attributes such as the CA (Certification Authority) certificate, the TLS client or server certificate, and a private key; this collection of data is identified by an alias name that may be a well-known value if the device only hold a unique identity.

Reset resets the EAP-TLS state machine.

Process-EAP forwards EAP-TLS packets to the secure microcontroller, which processes its contents according to the current state machine and returns an EAP-TLS packet. The EAP-TLS standard (see RFC 5126) specifies the transport of TLS over the EAP framework (Extensible Authentication Protocol, RFC 3748). A double segmentation/reassembly procedure performed both for EAP and ISO7816 messages, realizes the transfer of TLS packets (up to 16384 bytes) to and from secure microcontrollers whose (ISO7816) command size is limited to 256 bytes.

Get-CipherSuite collects the cipher suite (algorithms used for cipher and HMAC purposes) negotiated during the TLS session establishment; if available this command returns also the Session-Id of the current TLS session.

Get-KeysBlock returns a couple (for data transmission and reception) of cryptographic keys, needed by the record layer entity for encryption and integrity procedures, Due to performances issues (cryptographic operations performed by secure microcontrollers are not fast), the TLS session may be exported from the secure microcontroller if a great amount of exchanged data is expected.

Get-Result and *Fetch-Result* are service commands used to collect EAP packets that are produced by the secure microcontroller.

Write-Container pushes a set of data (the container) that are ciphered with the secure microcontroller public key (found in its certificate) and signed by a trusted authority.

The TLS application is downloaded in the TIST token during the manufacturing process. The administrator PIN is set by default to eight zeros. It may be thereafter modified, and its knowledge gives access to personalization operations, which imply the generation of identity attributes and their downloading in the secure microcontroller.

V. USING TIST FROM APIS

The TIST works with two class of computing platforms, laptops equipped with USB connectivity, and mobile phones supporting NFC interface. Two kinds of APIs are available written in C language for PC running the Windows operating system, and JAVA for Android smartphones.

A. APIs for C environment

The glue with PC/SC Windows environment is realized by five functions performing smartcards detection and ISO7816-4 commands exchanges.

- int DetectAllCard(char *Aid), returns the number of detected TLS modules.

- int StartFirstCard(int index,char *aid), starts a session with a smartcard identified by its index (first index is set to zero).

- int GetPtcol(int index), returns the T-Protocol (ISO7816 transport protocol) used by a smartcard identified by its index.

- int CloseCard(int index) closes a session with a smartcard identified by its index.

- int send_apdu(int index, char *request, int offset, int length, char *response, int response_offset) sends an ISO7816 command to a smartcard.

TLS sessions are opened by secure microcontrollers. Upon success, a set of ephemeral cryptographic keys (the KeysBlock) and the list of negotiated algorithms (the CipherSuite parameter) are read from the smartcard. They are handled by six procedures.

- BOOLEAN OpenSSLClient(int index, SOCKET s), opens a TLS session with a client EAP-TLS device identified by its index and a TCP/IP socket.

- BOOLEAN OpenSSLServer(int index, SOCKET s), opens a TLS session with a server EAP-TLS device identified by its index and a TCP/IP socket.

- int GetKey(int index, short *cs, char *key), collects the negotiated CipherSuite and the KeysBlock from a EAP-TLS device identified by its index and returns the keys size.

- int recordlayer(short cs, char* keybloc,CTX* ctx, int mode), creates a record layer (either CLIENT or SERVER side), working with a CipherSuite (cs) and a KeysBlock.

- int SSLRead(SOCKET s, char *buf, CTX *ctx), reads information over TLS associated to a TCP/IP socket and returns the data size.

- int SSLWrite(SOCKET s, char *buf, int len, CTX *ctx), writes information over TLS associated to a TCP/IP socket, returns the number of sent bytes.

B. APIs for JAVA environment

Two main java objects are required, the ***tls-tandem*** class building the core framework for the management of TLS session with an EAP-TLS RFID, and the ***recordlayer*** class created at the end of the TLS handshake, which performs all encryption decryption/operations.

The tls-tandem class is made of three main methods:

- public tls_tandem(int mode, ReaderSC reader, String aid, String pin, String identity)

- public recordlayer OpenSession(String ServerName, short Port)

- public void CloseSession(recordlayer RecordLayer)

The constructor of the tls-tandem class setups the software environment for TLS operations with external RFID, according to the following parameters,

- mode is the role of the RFID (either TLS CLIENT or TLS SERVER)

- reader is an abstract representation of the RFID reader, based on the NFC Android model. This object detects the presence of an external RFID feed by the reader, and provides support for IO operations.

- aid, is the Application Identifier for the application store in the RFID. According to the ISO7816 standard, this identifier size ranges between 5 to 16 bytes.

- pin is the optional PIN required for the RFID activation.

- identity is an optional alias that identifies the set of parameters (client's certificate, private key, CA Certificate) to be used by the TLS stack.

The OpenSession method performs the handshake with a remote TLS server identified by its name and its port (usually 443). It returns a recordlayer object initialized with the appropriate cryptographic parameters.

The CloseSession method deletes the TLS framework and the associated resources.

The recordlayer object is created upon a successful TLS handshake. It supports five main methods.

- public byte [] encrypt(byte[] msg). Perform encryption and integrity operations, and return a TLS formatted packet.

- public byte[] send(). Transmit a TLS packet over the TCP socket.

- public byte[] recv(). Receive a TLS packet from the TCP socket.

- public byte [] decrypt(byte[] msg). Decrypt a TLS packet and check its integrity.

- public void Close(). Close the TLS session.

VI. CONCLUSION

In this paper we introduced a new technology dealing with NFC, MIFARE and USB connectivity, which performs identity and access control services, compatible with both the OPENID standard and the MIFARE ecosystem deployed for electronics locks.

REFERENCES

[1] IETF Draft, "EAP support in smartcards", 2002-2012

[2] Urien, P., "Collaboration of SSL smart cards within the WEB2 landscape", CTS'09, 2009

[3] "An OpenID Provider based on SSL Smart Cards", Consumer Communications and Networking Conference, IEEE CCNC 2010, *Best demonstration Award*

[4] IETF Workshop, "Interconnecting Smart Objects with the Internet Workshop", Prague, March 2011.

[5] Urien, P., Kiennert, C. "A new key delivering platform based on NFC enabled Android phone and Dual Interfaces EAP-TLS contactless smartcards", in proceedings of MOBICASE 2011.

[6] Urien, P., Kiennert, C. "A New Keying System for RFID Lock Based on SSL Dual Interface NFC Chips and Android Mobiles", IEEE CCNC 2012

[7] Jurgensen, T.M. ET. al., "Smart Cards: The Developer's Toolkit", Prentice Hall PTR, 2002, ISBN 0130937304.

[8] P.Urien, "Convergent Identity: Seamless OPENID services for 3G dongles using SSL enabled USIM smart cards", IEEE CCNC 2011.

KNX-Based Home Automation Systems for Android Mobile Devices

G. De Luca, P. Lillo, L. Mainetti, V. Mighali, L. Patrono, I. Sergi
Dept. of Innovation Engineering
University of Salento
Lecce, Italy
{luca.mainetti, vincenzo.mighali, luigi.patrono, ilaria.sergi}@unisalento.it

***Abstract*—The adoption of smart environments is becoming more and more important in many applicative scenarios such as healthcare, asset management, environmental monitoring, and building automation. This last issue represents a very attractive use-case because of several scientific challenges that must be addressed in order to satisfy user requirements, which are mainly focused on the management of home's comfort parameters. The main goal of this work is to develop and validate an architecture, both hardware and software, able to monitor and manage a Konnex-based home automation system through an Android mobile device in an efficient and safe way. In this perspective, an Android application is realized based on a specific Java library, called Calimero, that provides several methods for interaction with the Konnex implant. Furthermore, a software system able to configure the Android application consistently with the home automation implant is designed and implemented. The proposed architecture was tested from both functional and performance point of view and the obtained results prove that it provides high performance in comparison with other solutions already affirmed on the market.**

Keywords- KNX; Android; Smart Home; ETS; Test bed.

I. INTRODUCTION

The ability to sense environmental parameters is becoming more and more important in many applicative scenarios. This trend aims to spread smart environments able to capture, in a pervasive way, all useful information from the real world, contributing to assert the Internet of Things (IoT) concept. It refers to the extension of the Internet to the world of concrete objects and places, which can communicate data about themselves and access aggregated information from other objects or places. In this way, the Human-to-Machine (H2M) paradigm is increasingly moving toward the new Machine-to-Machine (M2M) paradigm, so leading to an improvement of several aspects in everyday life. In this context, cities management (Smart City), energy saving (Smart Energy), buildings and homes automation (Smart Building and Smart Home) are typical scenarios for the use of such technologies. Among these potential applications, home and building automation issues are particularly important, since they represent the link among the individual (city dweller, consumer) and abstraction layers allowing the adoption of the IoT paradigm.

Smart Home & Building applications are wide and varied since there are many fields where they can be applied. In addition to well-established solutions, there are various projects in experimental stage, which mainly concern the energy consumption and security management, implant maintenance, and environment management.

Another technological component, closely related to the automated home management, is represented by mobile devices. They are becoming more and more important in everyday life, since they are not only communication means, but also technological tools for controlling other devices. However, in the home automation field, the integration among the mobile world and home automation systems encounters several limits generally due to poorly user-friendly application, the inability to remotely control the home automation system, and the low security level in the data exchange between mobile device and home automation system.

Therefore, the aim of this work is to propose an automation system able to overcome these limits. The system allows the user to monitor and manage a home automation implant in a flexible, simple and safe way by providing a high level of abstraction of real devices. For this purpose, an architecture, able to combine the widespread Android Operating System (OS) and Konnex (KNX) standard [1], was designed and developed. The functional validation of the proposed architecture was carried out in collaboration with Gewiss S.p.A. company of Bergamo (Italy) [2], that is one of the most important vendors for building automation solutions. By exploiting this important industrial support, a real KNX system was configured in order to test the designed and implemented architecture. This functional validation showed that, through the proposed solution, it is possible to safely control each KNX device both locally and remotely and to monitor implant status anytime and anywhere thanks to the real-time feedbacks sent by the home automation system to Android device. The peculiar feature of the proposed application is that it can be downloaded from the Android market as "generic application", that means without any customization. Then, after the installation of the KNX implant, it can be consistently customized for the specific home automation system by using the output file provided by the Engineering Tool Software (ETS) [3].

Finally, a performance validation was carried out to demonstrate the effectiveness of the proposed architecture.

The paper is structured as follows. In Section II, the state of the art on KNX-based home automation systems and on techniques used for their management is summarized. In Section III, a technical overview of the main standards and software libraries used in this work is presented. In Section

IV, the proposed architecture is described and all its features are presented. The test environment used to validate the whole system is shown in Section V, whereas the functional and performance validation results are discussed in Section VI. Conclusions are drawn in Section VII.

II. RELATED WORK

In recent literature, the topic of smart environment is widely discussed, and particular attention is given to Home and Building Automation systems based on the KNX standard. This topic is addressed according to three main aspects: safety, congestion control, and energy saving in domestic implants. From the safety point of view, in [4], a technique to guarantee a secure data transmission for home and building automation networks is proposed and implemented in a KNX-based environment, which does not natively provide any security mechanism.

The congestion problem is addressed in [5] and [6]. In KNXnet/Internet Protocol (IP) systems this problem is due to the presence of a particular device, called KNXnet/IP router, that allows the integration of different KNX networks through an IP network. Since the bandwidth of a KNX network is limited, if the KNXnet/IP router receives more messages than it is able to send, it can represent a bottleneck in routing these messages to the KNX devices. For this reason, in [6], authors recommend the adoption of efficient forwarding rules in the implementation of KNXnet/IP routers.

The home energy consumption is a topic of interest for both researchers and consumers since it concerns the reduction of power consumption and the protection of the environment. In this context, in [7], a simulator of a household was developed and a strategy for the energy efficiency and user comfort based on neural networks was proposed and tested by using an experimental KNX-bus platform.

Beyond the aspects previously described, it is important to note that smart environments based on KNX standard are designed to improve the quality of people's lives by the creation of new systems able to control comfort parameters. To achieve this goal, the integration among wired and wireless networks is increasingly used. In [8], for example, the comfort into an office building is ensured by designing a KNX-based system joined with Wireless Sensor Network (WSN) [9][10] components able to monitor and control the lighting, heating and air ventilation. The use of a WSN provides the system with information about environment conditions allowing a better control of comfort parameters, with minimum energy consumption [11].

Another example of integration between a wireless technology and a KNX system is reported in [12], in which a ZigBee network, well suited to home automation, is integrated with the wired home automation system. A KNX/ZigBee gateway is proposed as an interface between KNX and ZigBee networks.

Finally, since the management of home automation systems is more and more entrusted to mobile devices, in [13], the design and implementation of an iPhone application that allows the integration of mobile devices in an existing KNX home automation system are presented. Similarly to this work, the Android market offers some applications, such as [14] and [15], which allow the management of a KNX-based implant through an Android device. However, such applications suffer some drawbacks particularly due to poor usability and a poor abstraction of real devices.

III. TECHNICAL OVERVIEW

In this section, the main technologies used in the present work are briefly described.

A. KNX

KNX is the worldwide standard for home and building control; it exploits a software tool, called ETS, for planning and designing implant of KNX-certified devices and for implementing interactions among these devices. Compared to conventional electrical installations, a smart control and automation system has clear benefits since all the different subsystems are integrated into the building, optimizing performance and energy efficiency by using the KNX bus.

The standard includes two different configuration modes for the home automation devices:

- System Mode (S-Mode) for well-trained KNX installers that want to realize sophisticated building control functions;
- Easy Mode (E-Mode), that provides limited functions compared to the S-Mode, and that it is intended for installers with basic KNX training.

The KNX standard allows each manufacturer to select the most ideal configuration mode and to choose the right combination for the target market segment and application.

B. Android Operating System

Android is a mobile Operating System (OS) developed by Google. It is based on the open Linux kernel and it is open source, which means developers can modify and customize the OS for each phone. Therefore, different Android-based phones may have different Graphical User Interfaces (GUIs) even though they use the same OS. Android phones typically come with several built-in applications and also support third-party programs. Developers can create programs for Android (Apps) using the free Android Software Developer Kit (SDK). Android programs are written in Java and run through Google's "Davlik" virtual machine, which is optimized for mobile devices. Users can download Android applications from the online Android Market.

C. Calimero

Calimero [16] is a Java library that enables the access to KNX systems. It consists of a collection of Java Application Programming Interfaces (APIs) fundamental for workstation-based KNX/European Installation Bus (EIB) applications. Still, these APIs can be used independently and their ease of use enables client applications to communicate with KNX devices hiding network protocol details. The development of Calimero evolves constantly and when new features have to be included, the developers try to add them maintaining both ease of use and a compact footprint. Therefore, a considerable reorganization effort was undertaken, leading to a redesign of the user API as well as internal architectural aspects. The new Calimero Next Generation (NG) API now supports additional connection protocols, management, property access, high-level convenience methods for common tasks, and more.

IV. PROPOSED SYSTEM ARCHITECTURE

In Figure 1, the proposed system architecture is shown. The KNX system is equipped with a special device, called KNX/IP router, which links the KNX environment to the IP network in order to exchange KNX messages with remote devices. The KNX/IP router communicates through the KNXnet/IP protocol and includes, in addition to the tunneling function for the point-to-point connection, the line coupler function (i.e. routing), which allows the IP router to distribute and receive messages to other lines and areas. Since in the considered scenario there is only one home automation implant, the KNX/IP router is used in tunneling mode in order to exchange messages with Android smartphone across the IP network.

As mentioned in the previous section, the communication between the Android application and the KNX system is enabled by the Calimero library, whereas the local Wi-Fi router features guarantee an adequate security level for the home automation system management. In fact, in addition to the local access guaranteed by the Wi-Fi access point, the end-user can remotely control the home automation system through the smartphone by using a Virtual Private Network (VPN) tunnel between mobile device and local router. Once this access occurred, whether local or remote, the end user can act on her/his home automation system devices (e.g., switch, dimmer, heating, air conditioning) and monitor the environment status at any time. Also a manual change on the home automation system is shown on the smartphone display in real-time.

It is important to note that the application downloaded from the Android Market is a generic application: once downloaded and started, the application asks the user for a configuration file; this file is produced by a Java application, called “App Configurator”, used by the technician in order to configure the App in accordance with user requirements. Relevant information for this configuration can be automatically extracted from the output file exported by ETS or they can be manually entered. These interactions are summarized in Figure 2. The App Configurator helps the technician to set up the access parameters, build the screens,

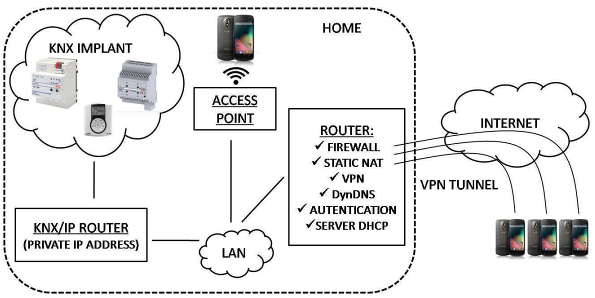

Figure 1. Proposed system architecture.

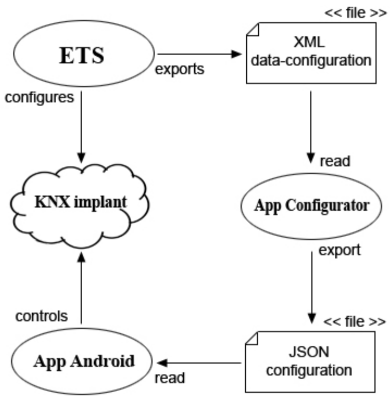

Figure 2. Android App configuration.

and place the control/monitoring components.

V. TEST ENVIRONMENT

The test environment used in the validation phase reflects a simple scenario of a two-floor home (Figure 3). The ground floor consists of a single room containing a light. The first floor consist of three rooms: a living room containing two lights and a thermostat; a bathroom containing a light (managed through a dimmer) and a rolling shutter; and a hall in which there are two controls that trigger two different home scenarios. In particular, these scenarios are: morning scenario (all lights are off and the rolling shutter is pulled up) and night scenario (all lights are on and the rolling shutter is lowered).

In order to reproduce the described environment, a system consisting of the following KNX devices was realized: actuators and push button panels for lighting, a dimmer, a power supply and a KNX/IP router. In particular, all electric devices used in the test are compliant with KNX standard and made by Gewiss.

Two different types of user access were emulated: a local Wi-Fi access, inside the home, and a 3G access for remote control. In particular, if the access to the KNX network is local, the wireless access point connected to the home router assigns a private address to the Android device by using its Dynamic Host Configuration Protocol (DHCP) server, so that the mobile device can communicate with the KNX/IP

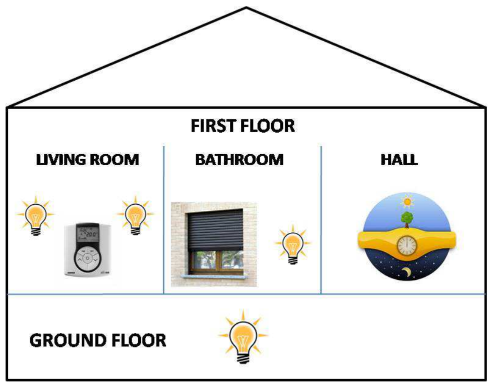

Figure 3. Test environment.

router. Instead, if the access is remote, a VPN tunnel is established between the smartphone and the home router. In this way, the smartphone becomes a local network device and it can communicate with the KNX/IP router as in the previous case.

VI. FUNCTIONAL VALIDATION AND SYSTEM PERFORMANCE

In the functional validation phase, the application was tested to demonstrate the effectiveness of the proposed architecture. In particular, each KNX device was successfully managed by using the Android application running on the smartphone. Furthermore, any status change manually carried out on the home automation system was displayed in the end-user interface.

In parallel to this test, another type of validation was performed. Its purpose was to demonstrate the efficiency of the proposed solution from the point of view of smartphone resources usage. In particular, the application was deployed on two different types of smartphone (i.e., Samsung Galaxy SIII and Samsung Galaxy Nexus) and it was compared with the two other applications already mentioned in Section II. The comparison results, reported in Table I, demonstrate that the proposed Android App is not only perfectly comparable to the other two applications for both the memory usage and CPU peak load, but it also shows to have higher performance. In fact, during this performance validation, the competitor applications were tested by managing only one or two devices, whereas the devices managed by the proposed application were eight. Similar results were obtained with both smartphone models.

VII. CONCLUSION AND FUTURE WORKS

In this work, the problem of the interaction between a KNX-based home automation system and an Android mobile device is afforded. More specifically, a complete hardware and software architecture has been designed, implemented and tested. The validation phase was carried out in laboratory by reproducing a real KNX home automation system. The proposed solution is able to guarantee an end-user secure access to monitor and manage the home automation system, both locally and remotely. The results obtained in both functional and performance validations are substantial. In fact, the proposed solution presents higher performance compared to other consolidated solutions.

Ongoing and future works aim to extend the application to the use of iOS mobile devices and to carry out a performance validation by comparing an increasing number of heterogeneous mobile devices. Finally, a more stressful validation of the proposed solution in wider scenarios (e.g. building automation) will be carried out, in order to further appreciate its flexibility and scalability.

TABLE I. PERFORMANCE VALIDATION RESULTS

	ayControl	**KNXController**	**Proposed solution**
Nr. devices	2	1	8
Memory usage	49 MB	41 MB	31 MB
CPU peak load	~ 30mW	~ 30mW	~ 30mW

ACKNOWLEDGMENT

The authors thank GEWISS SpA of Bergamo, ITALY, for their precious support.

REFERENCES

[1] http://www.knx.org/. Retrieved: March, 2013.

[2] http://www.gewiss.com/prv/it_IT.html. Retrieved: March, 2013.

[3] http://www.knx.org/knx-tools/ets4/description/. Retrieved: March, 2013.

[4] S. Cavalieri, G. Cutulu, and M. Malgeri, “A Studt on Security Mechanism in KNX-based Home/Building Automation Networks,” IEEE Conference on Emerging Technologies and Factory Automation (ETFA), pp. 1-4, Sept. 2010.

[5] G. Neugschwandtner and W. Kastner, “Congestion Control in Building Automation Networks: Considerations for KNX,” Industrial Electronics (IECON), Nov. 2009, 35th Annual Conference of IEEE, pp. 4149-4154.

[6] S. Cavalieri, “Estimating KNXnet/IP Routing Congetion,” Symposium on Industrial Electronics (ISIE), Jun. 2011, pp. 1200-1205.

[7] P. Kordìk, M. Hasaj, M. Tvdý, and M. Šnorek, “Building Automation Simulator and Control Strategy for Intelligent and Energy Efficient Home,” 3rd UKSim European Symposium on Computer Modeling and Simulation (EMS), Nov. 2009, pp. 154-159.

[8] C. Bujdei and S. A. Moraru, “Ensuring Comfort in Office Buildings: Design a KNX Monitoring and Control System,” 7th International Conference on Intelligent Environments (IE), Jul. 2011, pp. 222-229.

[9] L. Mainetti, L. Patrono, and A. Vilei, “Evolution of Wireless Sensor Networks Towards the Internet of Things: a Survey”, 19th International Conference on Software, Telecommunications and Computer Networks (SoftCOM), Sept. 2011, pp. 1-6.

[10] D. Alessandrelli, A. Azzarà, M. Petracca, C. Nastasi, and P. Pagano, “ScanTraffic: Smart Camera Network for Traffic Information Collection” Proc. European Conference on Wireless Sensor Networks, 2012, pp. 196-211, ISBN:9783642281686.

[11] D. Alessandrelli et al., “Performance Evaluation of an Energy-Efficient MAC Scheduler by using a Test Bed Approach”, Journal of Communication Software and Systems, vol 9, no 1, 2013, pp. 84-96.

[12] W. S. Lee and S. h. Homg, “Implementation of a KNX-ZigBee Gateway for Home Automation”, 13th IEEE International Symposium on Consumer Electronics (ISCE), May 2009, pp. 545-549.

[13] B. Bittins, J. Sieck, and M. Herzog “Supervision and Regulation of Home Automation Systems with Smartphones”, UKSim European Symposium on Computer Modeling and Simulation (EMS), Nov. 2010, pp. 444-448.

[14] http://aycontrol.com/en. Retrieved: March, 2013.

[15] https://sites.google.com/site/knxcontroller/. Retrieved: March, 2013.

[16] http://calimero.sourceforge.net/. Retrieved: March, 2013.

An Intelligence-Based Tool for Energy Management by Device Interoperability in Smart Houses

Andrea Capitanelli, Alessandra Papetti, Margherita Peruzzini, Michele Germani
Department of Industrial Engineering and Mathematical Sciences
Università Politecnica delle Marche
Ancona, Italy
e-mail: [a.capitanelli; a.papetti; m.peruzzini; m.germani]@univpm.it

***Abstract* — The recent developments in Information and Communication Technologies (ICT) and Internet of Things (IoT) make several house devices cooperate to each other to achieve higher energy performances and offer new services. However, the increasing embedded intelligence of smart devices is also generating a huge quantity of data, which must be properly managed. In fact, it is difficult to easily manage data to make certain functions available and to define a strategy for results maximization. This paper defines a methodology to improve smart home information management based on the selection, aggregation and classification of the sensible data and the correlation with the device typology, nature, and destination of use. Furthermore, a case study focused on washing machine is presented to demonstrate how this methodology can be implemented to realize a supporting tool encouraging service ideation to benefit the different subjects involved. The proposed model represents a first step towards the creation of a standard for smart house information management and device interoperability.**

Keywords - Smart houses; Smart information processing; Smart energy and optimal consumption; Intelligence-based service design; Device Interoperability.

I. Introduction

The actual growing world energy demand and the high attention to environmental impact reduction are generating a strong convergence of scientific, industrialists and politicians interests towards the use of Information and Communication Technologies (ICT) tools to support a more efficient use of the energy resources. In this regard, the concepts of "Smart Grid" and "Internet of Things" push a radical technological change where objects cooperate to achieve high-level objectives. They create a continuous flow of information that can be used to support real-time decisions, optimize the use of resources and increase safety and quality of life. Their application is particularly significant if considering that actually the residential sector is responsible for about 20% of total consumption and system usually operates without any users' cooperation.

Nowadays, the rising intelligence of smart devices can make a large amount of information available every day about personal actions as well as events taking place at home or outside. However, bad information management and difficulties in capturing and effectively transmitting essential data as well as interpreting such useful information for end-users, may drastically reduce the potential benefits and not encourage the diffusion of smart homes [1]. Therefore, a dedicated supporting tool must be designed and developed aiming to efficiently manage information on the basis of the users' purposes and ensure all the connected devices to be really interoperable. This scope is still an open issue in smart home system design [2].

The paper proposes a methodology to generate an innovative tool able to intelligently manage smart devices information in order to make them interoperable and provide tailored services to final users. It has been conceived for domestic environments, but it could be translated also in similar contexts. It provides to properly catalogue home devices and all the generated information, and it suggests how to realize an interoperable system able to implement home devices interoperability based on the correlation between system information categories and device classes. Furthermore, the paper adopts the proposed methodology to support a real use case focusing on washing machines: it allows identifying how to properly manage information for energy efficiency and how to provide a set of additional services according to the specific user needs.

The remainder of the paper is organized in four sections. Section II provides a quick overview on the state of the art of information management in smart houses. Section III describes the methodology steps and presents the information devices classification. Section IV illustrates the use case supporting the tool rationale definition for washing machine smart energy management.

II. Background on Information Management in Smart Houses

Over the years many definitions of smart home, also called smart houses, have been proposed [3]. The basic definition defines the smart home as a special home where all the sub-systems (lighting, security, household appliance, sensors, etc.) are interconnected allowing the homeowner to save energy, to reduce operating costs and to improve safety, comfort and multimedia services. In recent years, the technological research has focused on sub-systems integration, leading to the rapid growth of residential

 ISBN: 978-1-61208-282-0

gateways [4]. Thanks to a gateway, domotic solutions have the ability to manage all the devices connected to the home area network.

A considerable amount of new solutions for the smart home automation have been recently developed, i.e., several systems with different communication protocols and architectures. Existing systems can be classified into two groups: open systems and proprietary systems. The former, defined as "standard", are systems whose operating specifications are public to give companies the possibility to develop compatible devices. Well-known examples are: Konnex [5], Lonworks [6], Zigbee [7]. Proprietary systems are produced by software houses, which usually keep technical information as reserved and make them not available to third parties. Some examples are electrical and home automation systems: SCS by Bticino [8], Vimar By-Me [9], C-BUS of Schneider Electric [10].

The availability of common rules is fundamental to make devices interoperable when they are produced by different manufacturers [11]. It is expected that in the future home automation systems will be based on a single standard facilitating smart home management. However the issue of interoperability is particular challenging due to the huge amount of data to manage and the level of complexity of the devices' integration in the home area network. The introduction of smart appliances within a home network is not a new idea. However, it requires a more deepen investigation in respect with the actual strategies to achieve an efficient energy management. In particular, it entails understanding which functions a certain device is able to perform when connected to the network, what information can be sent and what for, and which commands must be received. In this context, the project CHAIN by the European Committee of Domestic Equipment Manufacturers (CECED) faced device interoperability issues and established a preliminary application profile for home connected, promoting the standard European Committee for Electrotechnical Standardization (CENELEC) in 2007 [12] [13]. However, the issue of interoperability between different home appliances is still open. Although numerous researches recently proposed different system architectures to obtain an integrated interoperable system, the existing system do not define an overall and unique standard data management tool, that is still missing. Actually, the majority of projects are focusing on the energy issue [14]. The most significant are: Smart Energy 2.0 (USA) [15], Energy@home (Italy) [16], EEBus/E-Energy (Germany) [17] [18]. All of them focus on network energy management via data exchange with smart grids and do not care about data elaboration and mining addressing high-level services. Indeed, the existing systems are finalized to provide a specific benefit or service such as monitoring, analyzing and estimating the energy consumption [19], even if they have great potentiality to be exploited for several purposes. Therefore, they have the advantage of introducing standard rules for the information exchange between the users and the utilities.

In addition to energy information management, many other services could be integrated thanks to the existing technological infrastructures. However, there is a lack of an overall vision and a strategic roadmap for future developments. Services related to devices remote control have been proposed but there are some open issues regarding their implementation on the white goods [20]. Also appliances remote maintenance concept is studied to provide benefits for both users and companies, but it has been considered as a concept independently of any architecture and available tools capabilities [21].

For this reason, the paper aims to identify and classify the involved information and defines the tool rationale to support service ideation satisfying the needs of the different subjects involved and achieving bigger advantages. The classification proposed aims to provide an overall vision of the smart house as a whole, able to consider all information necessary to include different services cited and encourage their continuous improvement. The idea to create a smart management tool supporting an integrated system also paves the way for companies to carry out market analysis and service tailoring, which are still ignored in this context. Furthermore, a possible innovation is represented by the use of the information generated by white goods for the elder people assistance, which is currently not exploited for such scope.

III. RESEARCH APPROACH AND SYSTEM ARCHITECTURE

By definition a smart home has a lot of smart devices connected to the Home Area Network (HAN), which collect and/or exchange information about some specific aspects. The research approach aims to guarantee the classification, aggregation and selection of all the information according to the device typology, and identify a strategy to manage all the involved information by an intelligence-based information management tool. The proposed approach consists of five main steps:

1) Classification of smart home devices into a set of homogenous classes (for typology, treated data, home interaction modalities, etc.);

2) Definition of a possible system architecture able to effectively realize the desired information management and device interoperability;

3) Identification of a general information management model characterized by information categories that are significant for the smart home;

4) Correlation between device classes and information categories to match their specific funtioning with the general information management model;

5) Definition of a set of application rule, to be impemennted intelligence-based information management, to design services on the basis of the users' needs.

A. Smart home devices classification

The most popular devices in smart home have been analyzed and classified into a set of homogeneous classes as follows.

Meters: this class includes electricity, gas and water meters, whose data are communicated through the home network and the smart grid. Control and safety systems (e.g. electrical safety, gas leaks, water leaks) are included in this category. Indeed, it is possible to detect gas or water leak in real time and, consequently, shut off the corresponding meter remotely.

Consumer electronics: it includes entertainment systems (e.g., tv, game console, audio equipment and players) and small household appliances (e.g., coffee makers, electronic cutters or graters, toasters). They typically have low and constant energy consumption and can be easily switched off/on by a remote control without any preventative measures. For this category the power consumption can be simply monitored as well as its usage (e.g., when and how long they are used; state of devices to allow a remote control).

Household appliances: it includes the major household appliances grouped as cooling (refrigerator and freezer), cooking (oven, hob, and hood) and laundry (washer, dryer, and dishwasher), enhanced by some items: to be interoperable, they require a microcontroller [13] that manages the processes during the automatic operation mode as well as the remote control mode; to be connected to a home network, they need a communication node that it can be installed on board or located outside (e.g., a cheaper solution has been developed by Indesit Company, called "Ultra-Low cost Power-line" (ULP) [22]). The communication node can also contain the energy control technology (e.g., Dynamic Demand Control (DDC) [23]).

Lighting, doors/windows, and security: it comprehends common classes of components such as lighting, doors, windows, window curtains and shutters. All of them can be controlled by similar functions (e.g. turn on/off, intensity regulation, opening/closing control, opening regulation). This category also includes the intrusion detection sensors for doors and windows of a generic alarm system. Information characterizing these devices is typically used for remote control and interaction analysis. In particular, thanks to motion sensors for automatic light switching, it also allows users to be localized and abnormal behaviors to be detected by recording the user's movements. It may be useful for Ambient Assisted Living (AAL) scopes to improve safety and human health.

DHW and HVAC: it includes Domestic Hot Water devices (DHW), Heating, Ventilation and Air Conditioning devices (HVAC), and all the devices and sensors related to their functioning, even when located in different areas or on other devices (e.g., sensors of indoor/outdoor temperature, humidity sensors, etc.).

B. Smart home interoperable architecture

The creation of an interoperable system able to mutually control all the devices and properly manage all the necessary data requires: a) the physical device connection to an HAN and b) the communication infrastructure. These items guarantee to deliver all the collected data to a central management tool and make data available for other systems or services (e.g., data analysis and data mining applications, user monitoring, remote control).

The existing physical connections have different capabilities in terms of distance, speed and volume data transfer. The list below shows the physical media that can be actually used in the smart home for interoperability purposes.

Power line: it can be realized by exploiting the existing house wiring that supplies all the electrical devices and the Power Line Communication (PLC) technology. Since every home already has it, power line is convenient and does not require any additional wiring. The most common communication standards for power line are X10 [24], HomePlug [25], and LonWorks [6]. However interference and noise issues inherently occur [26].

Phone line and other wiring: it includes all the other wirings of the smart home, such as twisted pair, coaxial cable, fiber optic and others. They allow managing high bandwidth and huge quantity of data, as required by entertainment systems. Wired communication through these connections is more stable than the wireless one, as it is less subject to external interference; however it entails higher costs. Some wired communication standards are Ethernet, USB, and HomePNA.

Wireless network: it uses electromagnetic waves to connect devices and send/receive information. It is practical because it allows connecting numerous devices in an easy way, also including devices not connectable by a physical cable. However, there may cause some problems due to the signal propagation (i.e., distance, presence of physical barriers and interferences). Well-known wireless communication standards are ZigBee, Wi-Fi, and Bluetooth.

As far as the creation of a unique communication infrastructure is concerned, it is worth to consider that each device has different requirements in terms of connections and communication protocols and a residential gateway is required. The gateway concentrates all data and serves as a bridge between the HAN and the Internet to exploits other systems or web services [27]. The user interface can be local (e.g., system display) or remote (e.g., web application or smartphone app). The user will monitor home conditions, control the devices and be informed about specific. Furthermore also utilities and companies can access some data transmitted from the smart home, according to the privacy policy, for specific services (e.g., remote assistance).

The described architecture represents a valid structure to implement the methodology and tool proposed in this paper.

C. The system information management model

Such a complex architecture requires managing a large amount of data derived from home devices, understanding their explicit and tacit relationships, and identifying a set of algorithms to realize functions and services. For these purposes all relevant information has been classified and algorithms investigated. In this context, several classification criteria have been already proposed [28] [29]. However the proposed model merges theoretical studies and industrial experience and has been validated by practical cases to satisfy the research goals. The model is based on four information categories and their correlation with the devices classes as presented in Table I. The selected categories are described below.

TABLE I. CORRELATION MATRIX BETWEEN SYSTEM INFORMATION CATEGORIES AND DEVICE CLASSES

			DEVICE CLASSES						
			Meters	**Consumer electronics**	**Household appliances**	**Lighting**	**Doors and windows**	**Security**	**DHW and HVAC**
INFORMATION CATEGORIES	**Continuous monitoring**	Ambient light level				x	x		
		Gas consumption	x		x				x
		Outdoor temperature					x		x
		Power consumption	x	x	x	x			x
		Rooms humidity							x
		Rooms temperature					x		x
		Video surveillance						x	
		Water consumption	x		x				x
	User interaction	Interaction time		x	x	x	x	x	x
		Scheduled on/off time		x	x	x			x
		Scheduled open/close					x		
		Set extra function			x				x
		Set light brightness				x			
		Set program			x				x
		Set speed			x				x
		Set temperature			x				x
		Shutting on/off time	x						
		User presence				x	x	x	x
	Control parameters	Air quality			x				x
		Air temperature			x				x
		Burnt out bulb			x	x			
		Component parameters			x				x
		Cycle time			x				
		Door lock			x				
		Electrical overload	x						
		Flow rate	x		x				x
		Intrusion detected						x	
		Noise level		x	x				x
		Pressure	x		x				x
		Short circuit	x						
		Water temperature			x				x
	State parameters	Cycle in progress			x				
		Light Brightness				x			
		Load presence			x				
		On/Off	x	x	x	x		x	x
		Open/Close			x		x		
		Opening rate					x		
		Standby		x	x				x

Continuous monitoring category: it includes all the information that is continuously monitored when the appliances are turned on. They mainly consist of resources consumption data (e.g., energy, water, etc.). They are used to provide a direct feedback to final users, who are encouraged to make a more efficient use of energy as demonstrated by recent studies [30].

User interaction category: it refers to all the information regarding the user-product interaction and characterizing the users behaviors (e.g., selected options, duration of use, time of use, frequency, etc.). Generally, data are aggregated for statistic analysis to define significant user profiles or frequently events as well as for marketing analysis. Data are usually sent when required.

Control parameters category: it comprises all data referring to the functional device parameters, which serve for supervising the device function or the user security. They are continuously analyzed and compare with a set of target parameters to predict a problem or detect dangerous conditions. Generally, they are forwarded to companies or service providers when a specific threshold is exceed.

State parameters category: it refers to all information regarding the device state in a particular scenario and carrying out the remote control.

The classification can also include two extra categories, which are not directly linked to the devices but they are from other entities. They are:

External data: they are generated by external entities but provide useful information about the scenario (e.g., building typology, occupants' characteristics, economic indicators, fees of utilities, climatic conditions). Also reference information (e.g., datasheets, standard consumptions, etc.) about the smart appliances provided by the manufactures can be included.

Derived data: they are obtained by other data elaboration such as statistics analysis and post-processing for realizing specific service functionalities (e.g., average time of use, average expenditure over the time, use frequency of a particular function).

IV. USE CASE: WASHING MACHINE SMART ENERGY MANAGEMENT

This section presents how the proposed approach can be implemented and how an energy management tool can be used for supporting washing machine use. The case study focuses on household appliances that represent one of the most challenging class since they combine mechanical, electrical and IT parts and having a strong interaction with the final user. As a consequence, the use case allows testing the approach in a complex scenario by using the proposed tool to manage a huge quantity of information and to delivery some related services. Among all white goods, the use case focuses on washing machines that are probably the most common appliance.

 ISBN: 978-1-61208-282-0

The first step was classifying all the information provided by the *washing machine* item. The second step was defining how to manage each specific data for each information category. The model application to the use case is shown in Figure 1.

Continuous monitoring data are monitored in real time and their management is mainly finalized to improve the use of energy resources and save money. Final users can compare real consumptions with the target ones, view and analyze historical trends, see how they evolve over time, and receive useful advices by exploiting also *External data* (e.g., how to use the washing machine to save energy or when to use it to save money according to the energy fee policy or providing interesting commercial offers on the basis of the user's needs). Furthermore, grid frequency information is useful to implement the DDC technology [23] and utilities could encourage this solution by rewarding users with cost reduction.

User interaction data monitoring allow companies analyzing how their customers act, which programs or functions are more frequently selected, and whether a specific product feature is successful as expected. The analysis of the users' habits can also support the definition of new functions and product options. Indeed, household appliances are generally optimized according to the standards and the customer habits, but real data can confirm or rebut such preliminary statements. Standard market analyses do not always provide truthful and accurate data because they depend on sample users' collaboration and personal subjectivity. In the use case, statistics will be based on the observation and direct analysis of user-product interaction. Such information are used by manufacturing companies and service providers: the former can identify a set of user profiles and optimize their products for each of them, and the latter can conceive and propose services according to their effective needs. Combining this information with *External data* (e.g., number of people, location, profession) allows characterizing users according to different parameters to improve the company strategies by low cost investments. Data concerning user interaction can be also analyzed to extract relevant information useful for elderly assistance to evaluate their quality of life and ensure their independence. For example, changes in user behavior or loss of abilities (memory problems, oblivions, etc.) can be detected by monitoring wrong actions and/or forgetfulness. Furthermore, users may be guided to choose the best washing program according to the clothes typology.

Control parameters allow directly interacting with devices at work for different purposes. For instance, corrective maintenance can be replaced by more accurate preventive or predictive actions. Manufacturers and users can agree to obtain mutual benefits: the company staff monitors some specific parameters to prevent failures and observe the appliance behavior to improve the product itself; contemporarily users have a continuous assistance and benefit from the reduction of product failure rate and downtime, and from a lower product consumption. It can support observing a malfunctioning, which is usually not detected also for a long time while product consumptions increase. In the use case, monitoring the selected parameters allows analyzing cycle execution and verifying if performances are good as desired. When real data exceed the defined thresholds, the manufacturer (or the technical assistance company) is noticed, predictive maintenance actions are scheduled, and the user is informed.

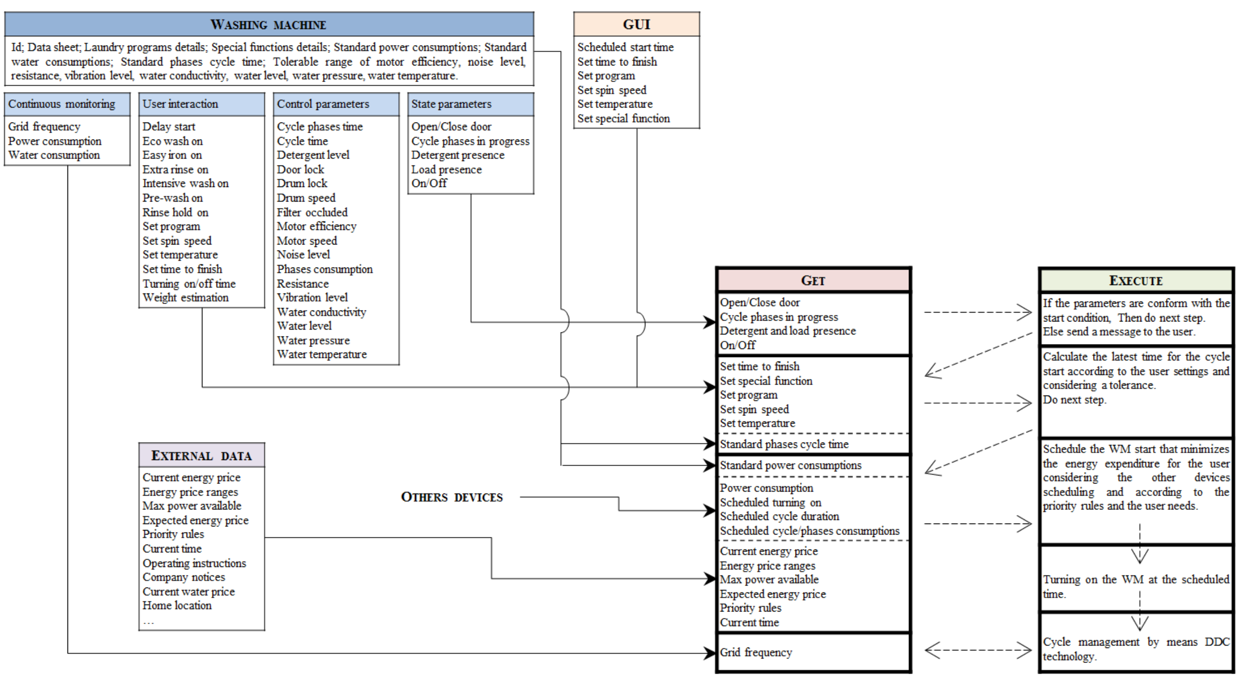

Figure 1. Tool rationale to schedule the washing machine start.

The proposed tool also facilitates the implementation of device remote control, which is a crucial aspect to guarantee people safety and comfort. The customer can visualize whether and how the machine is working at home, and remotely start, stop or change the washing program. The *state parameters* information is the basis to realize such a service. In fact, to do the remote control, the washing machine door has to be closed and system has to know if there is a cycle in progress. Furthermore, it is favorable to know if the load or detergent is not present in the machine in order to the remote control is not activated unnecessarily. Figure 1 presents the tool rationale and shows how the proposed model has been implemented for the use case. Identification of the user needs and system goals represents the first step for the development of the rationale behind the tool. For the proposed use case, the goal is scheduling the machine start to minimize the cycle energy cost according to the user's preferences. The user can select the *set time to finish* and the laundry cycle settings directly on the washing machine control panel or through the GUI. According to the information received and read, grouped in the GET table, the tool performs the actions described in the EXECUTE table to achieve the expected purpose.

V. CONCLUSIONS AND FUTURE WORKS

This paper presented a methodology to improve smart home information management promoting device interoperability. It allows classifying data originated by different smart appliances and matching them with an information management model to propose intelligence-based services. The research represents the first step to create a standard for information management and system interoperability, which can be applied also for other applications. The use case focused on washing machines and shown how to intelligently control data to save energy and provide energy-based services. Future works will consider a more detailed information asset, a wider devices' classification and will assess the achieved benefits by Life Cycle Assessment (LCA) and Life Cycle Costing (LCC). In this way, a more reliable methodology will be defined and a more robust aggregation of data will be managed. The proposed tool paves the way to the creation of standard systems the future smart home.

REFERENCES

[1] S. L. Kim and J. Hwang, "Real-time Energy Monitoring and Controlling System based on ZigBee Sensor Networks," Procedia Computer Science, vol. 5, pp. 794-797, 2011.

[2] C. Y. Chen, Y. P. Tsou, S. C. Liao, and C. T. Lin, "Implementing the Design of Smart Home and Achieving Energy Conservation," 7th IEEE International Conference on Industrial Informatics (INDIN 2009), Jun. 2009, pp. 273-276.

[3] J. K. W. Wong, H. Li, and S. W. Wang, "Intelligent building research: a review," Automation in Construction, vol. 14, pp. 143-159, 2005.

[4] T. Perumal, A. R. Ramli, C. Y. Leong, K. Samsudin, and S. Mansor, "Interoperability Among Heterogeneous Systems in Smart Home Environment," Atlantis Ambient and Pervasive Intelligence, vol. 2, pp. 141-157, 2010.

[5] www.knx.org, 2013.

[6] www.echelon.com, 2013.

[7] www.zigbee.org, 2013.

[8] www.bticino.it, 2013.

[9] www.vimar.it, 2013.

[10] www.schneider-electric.com, 2013.

[11] A. Kailas, V. Cecchi, and A. Mukherjee, "A Survey of Communications and Networking Technologies for Energy Management in Buildings and Home Automation," Hindawi Publishing Corporation Journal of Computer Networks and Communications, Article ID 932181, 2012.

[12] http://www.cenelec.eu/dyn/www/f?p=WEB:110:31348057 71974213::::FSP_PROJECT,FSP_LANG_ID:16860,25

[13] http://www.cenelec.eu/dyn/www/f?p=WEB:110:35577073 2961203::::FSP_PROJECT,FSP_LANG_ID:21849,25

[14] M. R. Alam, M. B. I. Reaz, and M. A. M. Ali "A Review of Smart Homes-Past, Present, and Future," IEEE Transactions on Systems, Man, and Cybernetics-Part C: Applications and Reviews, vol. 42, pp. 1190-1203, 2012.

[15] www.zigbee.org/SmartEnergy/, 2013.

[16] www.energy-home.it, 2013.

[17] www.eebus.org, 2013.

[18] www.e-energy.de, 2013.

[19] J. Shin and J. Hwang, "Intelligent energy information service based on a multi-home environment," Procedia Computer Science, vol. 10, pp. 197-204, 2012.

[20] P. Bansal, E. Vineyard, and O. Abdelaziz, "Advances in household appliances - A review," Applied Thermal Engineering, vol. 31, pp. 3748-3760, 2011.

[21] A. Mullera, A. C. Marquezb, and B. Iung, "On the concept of e-maintenance: Review and current research," Reliability Engineering and System Safety, vol. 93, pp. 1165-1187, 2008.

[22] A. Ricci, V. Aisa, V. Cascio, G. Matrella, and P. Ciampolini, "Connecting electrical appliances to a Home Network using low-cost Power-Line Communication," International Symposium on Power Line Communications and Its Applications, Apr. 2005, pp. 300-304.

[23] A. Ricci, B. Vinerba, E. Smargiassi, I. De Munari, V. Aisa, and P. Ciampolini, "Power-Grid Load Balancing by Using Smart Home Appliances," Digest of Technical Papers. International Conference on Consumer Electronics ICCE, Jan. 2008, pp. 1-2.

[24] www.x10.org, 2013.

[25] www.homeplug.org, 2013.

[26] A. Usman and S. H. Shami, "Evolution of Communication Technologies for Smart Grid applications," Renewable and Sustainable Energy Reviews, vol. 19, pp. 191-199, 2013.

[27] S. T. Cheng, C. H. Wang, and G. J. Horng, "OSGi-based smart home architecture for heterogeneous network," Expert Systems with Applications, vol. 39, pp. 12418-12429, 2012.

[28] M. J. Kofler, C. Reinisch, and W. Kastner, "A semantic representation of energy-related information in future smart homes," Energy and Buildings, vol. 47, pp. 169-179, 2012.

[29] L. G. Swan and V. I. Ugursal, "Modeling of end-use energy consumption in the residential sector: A review of modeling techniques," Renewable and Sustainable Energy Reviews, vol. 13, pp. 1819-1835, 2009.

[30] D. Bonino, F. Corno, and L. De Russis, "Home energy consumption feedback: A user survey," Energy and Buildings, vol. 47, pp. 383-393, 2012.

 ISBN: 978-1-61208-282-0

Event-Driven Communication on Application Level in a Smart Home

Christoph Soellner, Uwe Baumgarten
Chair for Operating Systems (F13)
Technische Universitaet Muenchen
Munich, Germany
{cs, baumgaru}@tum.de

***Abstract*—In recent years, research on the Internet of Things focused on wired or wireless information transport. Progress has been made in energy-efficiency, reduction of bandwidth usage and bringing standard Internet protocols to small resource constrained devices. Yet, an application level protocol that not only aims at enabling such devices for remote control but at the same time also offers semantic description features to human users is not found. Based upon previous work, we introduce further semantic schema extensions, add event-based communication on application level and compare our approach to existing work.**

Keywords—Smart Home; Smart Grid; Smart Device; remote control; Internet of Things; embedded system

I. INTRODUCTION

In a previous work [1], we introduced a straightforward concept aimed at tiny embedded devices to enable them for remote control on application level via Internet standard protocols. We showed how to use the Extensible Markup Language (XML) [2] to describe devices and their capabilities. Furthermore, we used two methods (`GET` and `POST`) from the ReSTful hypertext transport protocol (HTTP) [3] to enable devices for basic remote control by standard HTTP clients.

We also described briefly our implementation that was written for the Atmel microcontroller unit (MCU) families *ATmega* [4] and *XMega* [5] with at least 16 kByte of program memory and 1 kByte of static RAM. The software features a state machine based HTTP parser written in *C* to process messages in a byte-sequential manner. Thus, it was intended be used over low-performance communication links that transmit one byte at a time only, such as a universal asynchronous receiver / transmitter (USART) link.

To also achieve a reduced memory footprint, the parser will process an HTTP message separated according to its components such as the method, the URL path, optionally its header information and body values. It does not store the message completely, but processes it on-the-fly instead.

In our concept we identified a few unresolved issues. First, numeric XML elements in some cases may not carry enough semantic information for a human user. Secondly, a Smart Home setup will require sensors and actuators to communicate upon certain conditions without a third party.

After recapitulating key elements of our concept in section II, we describe the introduction of additional XML elements to our schema and the extension of the control interface to also support event driven communication between Smart Devices in section III, and finally, compare our solution to existing protocols in section IV.

II. RELATED WORK

In our previous work [1], we proposed a hierarchical three-level XML based description of devices, where the first level offers device and meta information, the second level serves as a container to group machine state information semantically, and the third level carries said machine state information. We also introduced a ReSTful control interface, the commands of which are derived from a device's XML description.

Principal goals with our new approach were to show that already proven internet standard protocols can be processed on very resource constrained MCUs and to demonstrate the importance of communication layer separation. Within a Smart Home, IP based communication between all devices cannot be assumed; tasks such as addressing must be handled on application level alone, when only a broadcast message transport is available.

To demonstrate the protocol efficiency, we implemented our concept in *C* for Atmel AVR MCUs. By utilizing preprocessor macros, we ensure small code while at the same time providing comfortable configuration options to the developer. Modification of machinery state is done through callback functions which are implemented by the developer and registered with our library; they are called whenever the HTTP parser has determined a specific action from a received message.

An exemplary binary code, which utilizes our library, a USART communication driver and basic get/set functions consumes roughly 14 kByte of program memory space and thus fits into our target MCU family. It simulates a combined refrigerator / freezer device and serves as example in the subsequent sections, in which we will cover the ideas of the application level interface.

A. Service description

In general, we assume a Smart Device to be a black box and unique; there is no schema to a device, since, in principle, every vendor may choose to implement certain functionality in their own way. Therefore, a device must be queried for its capabilities, at least once before control operations are possible. Any Smart Device that implements our application interface and is queried for its features, will output an XML description as given in Fig 1. As mentioned, we operate solely on application level and cannot make any assumptions as to how the messages are relayed. In particular, we cannot assume IP based communication.

Furthermore, a principal concept is our integration of both semantic and machine-interpretable information into one single description, as depicted in Fig. 1.

```
<dev00010>
  <meta type="deviceName">TUM Refridgerator</meta>
  <meta type="manufacturerName">Chair F13, TUM</meta>
  <meta type="manufacturerURL">http://www.os.in.tum.de/</meta>
  <Fridge>
    <Door type="string" access="readonly">closed</Door>
    <CurrentTemperature type="float" access="readonly" ↵
     unit="°C">8.6</CurrentTemperature>
    <TargetTemperature type="float" access="readwrite" ↵
     min="4.0" max="16.0" unit="°C">8.0</TargetTemperature>
  </Fridge>
  <Freezer>
    <Door type="string" access="readonly">closed</Door>
    <CurrentTemperature type="float" access="readonly" ↵
     unit="°C">-17.6</CurrentTemperature>
    <TargetTemperature type="float" access="readwrite" ↵
     min="-30.0" max="-8.0" unit="°C">-18.0</TargetTemperature>
  </Freezer>
</dev00010>
```

Figure 1. XML discovery message of a Smart Device

We use one single XML document generated on-the-fly by the Smart Device to deliver both semantic information suited for a human user and machine state information intended for automated processing. Semantic information is given by naming XML elements appropriately, data relevant to machines is provided through a node's respective attributes and values. Thus, element names differ from device to device and are chosen appropriately according to generic XML node naming rules [6] by the developer. Node names are treated *case-sensitive*.

1) Device level

As denoted in the example, the first level node carries a unique id for a device (*dev00010*) and may further contain *meta* elements. Each of those consists of a designating *type* attribute and a corresponding *value*. It has, by definition, no meaning for machine-to-machine communication and is only presented to help a human user understand the device's purpose. Thus, it will be displayed unmodified to the user by the application. We allow and encourage simple interpretation such as displaying hyperlinks in a clickable manner.

2) Service level

The service level offers a way of displaying separate hardware parts within a Smart Device to a user. As shown in Fig. 1, both the refrigerator and the freezer can be described in a similar fashion; simply by naming the service nodes differently and semantically plausible, a human user is able to distinguish and interpret contained data more easily.

3) Data point level

The actual machine state information is contained in nodes on this level. Each *service* has at least one data point, where a data point represents a single value of one of three types: integer, floating point number and string. Each value will be derived from internal machine state by a callback function when queried and will be modified by a different callback function when written to.

Our library also features the definition of other attributes such as *min* and *max* boundaries for numerical data points, *access* restrictions to allow for readonly or writeonly data points and a *unit* string helping human users interpret a data point's value. When set, restrictions will automatically be enforced upon modification of data points before they are passed to the respective callback function.

```
>>> GET /dev00010/ HTTP/1.0
>>> GET / HTTP/1.0
    Host: dev00010
>>> GET /*/ HTTP/1.0
>>> GET / HTTP/1.0
    Host: *
```

Figure 2. A single or all devices are addressed via HTTP.

B. Control interface

In this subsection, we describe the ReSTful command interface for a Smart Device. The importance of a ReSTful interface for resource constrained devices has been discussed in [8]. Control messages follow the HTTP message specification. We allow `GET` to retrieve one or more data points and `POST` to modify machine states. Other verbs are not supported.

1) Device addressing

The message transportation layer is not required to feature device addressing on hardware or protocol level. Instead, addressing is done in software on application level with HTTP alone.

To address one single or all devices connected to the same medium, a regular HTTP request is used with the first part of the URI being the target device id or the asterisk, meaning 'any', as shown in Fig. 2.

```
>>> GET / HTTP/1.1
    Host: dev00010
    Host: anotherDevice0293
    Host: technicsStereo10023
```

Figure 3. Several devices are addressed in a multicast manner.

When communication with several devices in a single (application level) multicast request is required, we utilize HTTP's `Host:`-header to address those devices by their respective id. As allowed by the specification [3], the `Host:`-header is set several times in this case. Fig. 3 gives an example. Note that the host values could also be sent as comma separated values in one single line; however, this would increase parser complexity and is not supported by our code.

```
<?xml version="1.0">
<bus>
  <dev00010><!-- […] --></dev00010>
  <anotherDevice0293><!-- […] --></anotherDevice0293>
</bus>
```

Figure 4. The enclosing bus element is displayed.

Each well-formed XML document must have exactly one root element. Therefore, the first device to respond will output the XML header and an enclosing XML root element named `bus`, when more than one device is *addressed*, as shown in Fig. 4. It will be ignored in all requests to the devices; its purpose is merely to fulfill XML document specification.

2) Service discovery

Previous example requests already depicted the Smart Devices' service discovery procedure: The command `GET /` is used query all connected devices for their complete XML description, which includes any meta information and data point attributes. The resulting document is generated on-the-fly each time a discovery procedure is initiated. Note that reliability and security issues are handled on underlying levels according to application requirements.

```
>>> GET /dev00010/*/Door HTTP/1.1
<<< <dev00010>
      <Fridge><Door>closed</Door></Fridge>
      <Freezer><Door>closed</Door></Freezer>
    </dev00010>
```

Figure 5. Machine state information is retrieved by specifying an XPath selector in the URL path.

3) Retrieving data point values

We utilize a reduced XPath [7] implementation to retrieve machine state stored in data point values. To that end, the URL path is used as XPath selector of the virtual document of the discovery output of devices. The asterisk character may be used on any of the three hierarchical levels to select all instances on that level, as depicted in Fig. 5.

As shown, no *meta* information and no attributes are output when not in discovery mode; it is assumed that a client already completed the discovery procedure and stored its result for subsequent requests. Thus, a retransmission serves no purpose.

4) Modifying data point values

The HTTP method `POST` is used to modify machine state.

```
>>> POST /dev00010/Freezer/TargetTemperature HTTP/1.1

    -18.5
```

Figure 6. A single value is modified through a POST request.

To set a single data point on a single Smart Device, the URL can be used in the same manner as in II.B.3). The value to be written is transmitted in the message's body (Fig. 6).

```
>>> POST /dev00010/ HTTP/1.1

    Fridge.TargetTemperature=6.0&Freezer.TargetTemperature=-18.5

>>> POST /*/ HTTP/1.1

    *.TargetTemperature=0.0
```

Figure 7. Several values are changed in a single message.

In order to achieve application level manycast, several or all values within a single device or even several devices can be changed through one single broadcast message, as depicted in Fig. 7.

Note that the separating character in the HTTP body is the decimal instead the forward slash. Thus, we achieve compatibility with hypertext markup language (HTML) forms and can offer a simple web interface that is automatically generated from the service and data point definition.

III. CONCEPT EXTENSION

In our research, we came across certain use cases where the current schema does not suffice. In this section, we extend the description schema and the protocol.

A. Data point labels

Numeric data points can not only be used to represent sensor readouts, they may also represent discreet machine states. A door for instance may either be locked or unlocked; instead of using a string representation, in this case a Boolean value suffices.

In general, a numeric data point with its name alone may not offer sufficient semantic information to a human user for interpretation. We give examples within a Smart Home:

- A window handle sensor may for instance only take on values of *0*, *1* and *2*; where one could guess a semantic meaning for *0* (*closed*) it would be feasible to describe *1* as *flipped* and *2* as *open* during discovery.
- A laundry machine that features a static program list may encode the currently selected program only in a numeric value. However, also a human interpretable text representation is required for a consumer.
- A Smart Radio receiver may output a station list derived from an auto tune process or decoded radio data system messages to be displayed in a remote control application.

```
<radio00295>
  <meta type="deviceName">Smart Radio</meta>
  <Tuner>
    <Frequency type="float" access="readwrite" ↵
     min="87.5" max="108.0" unit="MHz">
      96.3
      <Label from="96.3" >Bell 96,3</Label>
      <Label from="97.5" >Antenna Bavaria</Label>
      <Label from="107.2">Antenna Bavaria</Label>
    </Frequency>
  </Tuner>
</radio00295>
```

Figure 8. The Label element with its attributes "from" and "to" is introduced.

We therefore introduce the `<Label>` element for data point elements with two attributes, describing a label's valid range: *from* and *to*. The attributes' restriction base is equal to the parenting data point's data type, i.e., *from* and *to* may carry floating point values only if the parent data point is of the type *float*. In case a label is only valid for a single data point value and thus both attributes would show the same value, *to* may be omitted (Fig. 8).

```
<sensor20912>
  <Brightness>
    <Value type="int" access="readonly" ↵
     min="0" max="120000" unit="lx">
      1050
      <Label from="0" to="2000">darkness</Label>
      <Label from="60000" to="120000">daylight</Label>
      <Label from="80000" to="90000" >bright sunlight</Label>
      <Label from="90001" to="120000">bright sunlight</Label>
    </Value>
  </Brightness>
</radio00295>
```

Figure 9. Overlapping ranges for Label elements are displayed.

To specify a range, *to* must be given. Both boundaries can also take on `INF` or `-INF` within *float* data points. Ranges of different labels may overlap (Fig. 9). In this case, the client presents all suitable Label element values for a given data point value to the user. Label values that are valid for more than one data point value are given as many times as required (third Label element servers as demonstration).

Note that the specified element has no impact on the HTTP parser complexity on the MCU; it is output in discovery mode only.

B. Event initiated communication

Our concept, so far, only supports communication for retrieval or modification of machine state initiated by control software through `GET` or `POST`. We extend it to also support event driven notifications sent by Smart Devices upon certain conditions. To signal an event, we introduce a new HTTP verb and define the message format in the following subsections.

1) HTTP message format

An event message can be sent for any data point. All event messages will be broadcast by the Smart Device generating it, thus being received by all other Smart Devices on the same logical message transport segment. Also, it may be forwarded into other networks by different protocols such as UDP/IP.

```
>>> EVENT /dev00010/Fridge/Door HTTP/1.1
>>>
>>> open
```

Figure 10. An exemplary Event message by the Smart Fridge device is shown.

Event messages have the same structure as HTTP messages; the verb designates an operation concerning a specified resource designated by the URL path and the body contains the new value.

To that end, we introduce the method `EVENT`. As opposed to regular HTTP messages and in compliance with our previous statement however, the URI path designates the path to the *originating* (and *not* the destination) data point as shown in Fig. 10.

Furthermore, each `EVENT` message carries exactly one data point value in its body. In case there are several changed data points, the respective amount of messages is required. As already mentioned, we rely on lower layers to implement reliability and security.

The advantage of keeping event notifications in an HTTP format and allowing only singular values within the body is, that only little modification to the HTTP parser is necessary. We still do not require XML parsing capabilities, but can rather utilize already present code to process an event.

Since there is no publish/subscribe mechanism with our concept, `EVENT` messages are not being replied to.

2) Implementation overview

To achieve described functionality we extend the HTTP parser: in case of an `EVENT` notification, a hash table stored on the device is queried to find a suitable mapping of the event's URL path and an internal data point address. The hash table stores every such path as a mapping between a zero-terminated character string and an unsigned integer containing the program memory address of the respective data point.

If a mapping is found at least once, the event's body value is passed to the registered callback function for each such match. Restrictions and other data type mapping apply in the same way as with a regular `POST` message.

Event notifications usually do not generate a response. However, when a data point is modified through an event, it *may* be configured to in turn broadcast an event to confirm the change. This is particularly useful for monitoring machine state: a light for instance may have been turned on by a hardware button, an event message or a `POST` request – in all three cases events may be generated and could displayed on a monitoring instance, regardless of the source of the modification.

We make no assumption as to when an event message needs to be sent; it ultimately depends on the application. The Smart Light controller for instance may send events for each light affected as soon as there is no change for a certain period of time; in this case, dimming the light would not result in event message flooding.

For efficient implementation we recommend placing the hash table into the MCU's EEPROM with a static limit on its size. Thus, a Smart Device may offer only a limited number of such direct connections with other Smart Devices.

We are aware that ReSTful interfaces were designed for request / response operation only and that it may seem inappropriate to encode *origination information* in a resource locator at first. However, ReST can also be viewed as a concept where the *method* operates on the *resource specified*, with no actual locations or addresses given.

```
<smartLight>
  <Bulb>
    <State type="int" access="readwrite" min="0" max="1">1</State>
    <Toggle type="int" access="writeonly" min="1" max="1" />
  </Bulb>
</smartLight>
```

Figure 11. An exemplary service description for a Smart Light controller is displayed.

3) Example

Consider a Smart Light controller that features two data points (Fig. 11). The first one, "State", turns the light on and off, according to the values 1 and 0 written to it, respectively. The second one, "Toggle", negates the current switch's state in case a "1" is written to it.

Secondly, consider a Smart Switch ("sw2013") with a single button (service "Button"), which in turn contains one data point names "Pressed". It broadcasts an Event on two occasions: a `1` when pressed, and a `0` when released.

We configure the `Toggle` data point on the light controller to accept event messages from `/sw2013/Button/Pressed`. Since `Toggle` only accepts a `1` value, all *release* events are ignored. Therefore, this configuration results in push button functionality.

IV. COMPARISON WITH OTHER PROTOCOLS

In this section, we compare our approach with existing application level protocols with regards to functionality, features, message size and –if possible– implementation details. Note that no assumptions over message transport or underlying protocols can be made, i.e., the Internet Protocol in particular and other well-known protocols like TCP / UDP or the DNS are not available.

A. XML protocols

There are already some protocols available to be used within a Smart Home scenario, mostly based on XML. Yazar and Dunkels compared a ReSTful control interface with a SOAP [9] based approach; they found SOAP to have a significantly larger memory footprint, execution time and message size [10].

Also, SOAP based protocols rely on a service schema description written in the Web Service Description Language (WSDL) which must be stored and processed separately.

Even with a limited subset of SOAP functionality, e.g., the devices profile for web services [11] (DPWS), we are restricted to SAX like parsing on the target embedded hardware, since a request may not fit into the device's memory as a whole. Thus, essential features such as name spaces, message integrity checks or verification against a given WSDL schema may not be available and limit compatibility with standard clients.

Lastly, SOAP makes heavy use of DNS and IP for message routing. As stated, those may not be available on a Smart Device network. Therefore, a SOAP based approach for message exchange seems not feasible for the Smart Home Scenario.

B. *Constrained Application Protocol*

Mainly designed as a binary replacement for HTTP, the constrained application protocol [12] (CoAP) aims at enabling resource constrained embedded devices for internet communications. It introduces application level reliability, offers simplified parsing through binary header representation instead of a text based one and remains largely compatible with HTTP through standardized command mappings.

CoAP achieves a reduced message size compared to HTTP. We can easily confirm this by counting octets, e.g., for the message in Fig. 6: while HTTP results in 58 octets, we achieve a significantly smaller size for the CoAP equivalent, 47 octets (4 header, URI-Path 1+8, URI-Path 1+8, URI-Path 2+17, 1 octet separator, 5 octets payload).

However, major disadvantages, as we noted in [1], include the limitation to only four methods, the duplication of TCP's features of reliability on application level (where this should remain on the transport layer) and the tight integration with IP/UDP respectively. Also, the code size of a commonly used reference implementation is about ~25 kByte of program memory space, and additionally, CoAP does not cover service description or discovery procedures.

C. *Constrained restful environments link format*

To overcome the latter, Shelby et al. [14] also proposed application layer schemata for service consumption, service directories and caches [13], the Constrained ReSTful Environments link format (CoRE). While in principle the CoRE can be run over any ReSTful interface, it was designed to specifically work over CoAP, since it relies on CoAP's request and response code mapping and requires it to handle all machine addressing tasks.

In the current version of the RFC, we can identify weaknesses in the text based protocol:

- Use of angle brackets ("<>"): Both characters are used in markup languages to denote descriptive information. Within CoRE, an actual resource location is designated between those characters, which may confuse both designers and restrictive firewall software; moreover, as the forward slash ("/") is explicitly allowed.
- Discovery entry point: It is not clear why a `/.well-known/core` URI is used for discovery. Common web browsers, for instance, use the much shorter GET command `GET /`.
- Parser complexity: While CoAP was designed specifically to reduce parser complexity on application level, this is negated with the CoRE approach. According to [14], complex query search and filtering tasks can optionally be supported by Smart Devices with query filtering. All optional parts introduce uncertainty and unreliability into a concept; moreover, it is not evaluated which filtering options are required in the first place on resource constrained devices.

Although CoAP is routed over UDP links and supports delayed responses, neither CoRE nor CoAP specify event based broadcast messages. A Smart Device would therefore always have to have routing and IP address information about desired recipients. Particularly in scenarios with dynamic IP addresses (met constantly within a Smart Home), CoAP message links may become cumbersome to maintain.

While we acknowledge that Smart Home functionality, i.e., retrieving and modifying machinery state, can be achieved by a CoRE protocol design, the authors fail to clarify the advantages of their concept over regular XML and XPATH expressions; a reference implementation enabling a comparison of both approaches under similar circumstances is not yet available.

Lastly, both CoAP and CoRE have a strong disadvantage in common: They both need to be implemented again for each programming language and type of network equipment (such as firewalls and application level gateways) that is to feature the protocol. This is not necessary with HTTP and XML.

V. Conclusion and Oulook

With the extension of our concept targeted at tiny embedded Smart Devices, we resolved the issues occurring with some use cases on application level.

Furthermore, with the introduction of the HTTP method `EVENT` we demonstrated how Smart Devices can initiate communication and how this approach can be leveraged to enable vendor-independent application level communication between Smart Devices without application level translation.

In future work, we address repeated transmission of event messages in case a certain condition persists and demonstrate an application level message routing software that allows third parties, such as a power utility, to influence machine behavior on occasion (e.g., emergencies or power overproduction).

Also, we evaluate our implementation against CoRE in more detail, once a properly maintained implementation becomes available.

References

[1] C. Soellner and U. Baumgarten, "Bridging the Last Mile in a Smart Home on Application Level", The 4th Int. Conf. on Smart Communications in Network Technologies (SaCoNeT2013), in press.

[2] E. Ray, "Learning XML", 2nd ed., O'Reilly, 2003.

[3] R. Fielding, J. Gettys, J. Mogul, H. Frystyk, L. Masinter, P. Leach, and T. Berners-Lee, "Hypertext Transport Protocol", Internet RFC 2616, Sep. 2004, Available: http://www.w3.org/Protocols/rfc2616/rfc2616-sec4.html#sec4.2, [retrieved April, 2013].

[4] Atmel vendor website, “megaAVR Microcontroller”, Available: http://www.atmel.com/products/microcontrollers/avr/megaavr.aspx, [retrieved May, 2013].

[5] Atmel vendor website, “AVR XMEGA Microcontroller”, Available: http://www.atmel.com/products/microcontrollers/avr/avr_xmega.aspx, [retrieved May, 2013].

[6] J. E. Simpson, “O’Reilly xml.com - The Naming of Parts”, Available: http://www.xml.com/pub/a/2001/07/25/namingparts.html, [retrieved April, 2013].

[7] M. Kay, “XPath 2.0 programmer's reference”, Indianapolis, IN: Wiley, 2004.

[8] D. Uckelmann, M. Harrison, and F. Michahelles, “Architecting the Internet of Things”, Springer-Verlag, Berlin, 2011, chapter 5.

[9] M. Gudgin et al., “SOAP Version 1.2 Part 1: Messaging Framework (Second Edition)”, W3C Recommendation, Available: http://www.w3.org/TR/soap12-part1/, [retrieved May, 2013].

[10] D. Yazar and A. Dunkels, “Effcient application integration in IP-based sensor networks”, In Proceedings of the First ACM Workshop on Embedded Sensing Systems for Energy-Effciency in Buildings, BuildSys'09, pages 43-48, New York, NY, USA, 2009. ACM.

[11] T. Nixon and A. Regnier, “Devices Profile for Web Services (DPWS)”, OASIS Standard, Available: http://docs.oasis-open.org/ws-dd/ns/dpws/2009/01, [retrieved April, 2013].

[12] Z. Shelby, K. Hartke, and C. Bormann, “Constrained Application Protocol (CoAP)”, Internet-Draft 16 (work in progress), Available: http://tools.ietf.org/html/draft-ietf-core-coap-16, [retrieved May, 2013].

[13] Z. Shelby, S. Krco and C. Bormann, “CoRE Resource Directory”, Internet-Draft 5, Available: http://www.ietf.org/id/draft-shelby-core-resource-directory-05.txt, [retrieved May, 2013].

[14] Z. Shelby, “Constrained RESTful Environments (CoRE) Link Format”, IETF RFC 6690, Available: http://www.rfc-editor.org/rfc/rfc6690.txt, [retrieved May, 2013].

Modeling of Activities as Multivariable Problems in Smart Homes
Case Study – Recognition of Simultaneous Activities

Farzad Amirjavid
Department of mathematics and computer science, UQAC
Chicoutimi, Canada
farzad.amirjavid@uqac.ca

Abdenour Bouzouane
Department of mathematics and computer science, UQAC
Chicoutimi, Canada
abdenour_bouzouane@uqac.ca

Bruno Bouchard
Department of mathematics and computer science, UQAC
Chicoutimi, Canada
bruno_bouchard@uqac.ca

Abstract— **Resident of a smart home, who may be an Alzheimer patient needing permanent assistance behaves non-linearly to achieve the intended goals. He actuates the world by realizing actions, activities which can be observed through the embedded sensors of the smart home. To assist him automatically and live independently at home, it is needed to capture information and knowledge from world to reason if the world state is normal and to evaluate how much the intelligent system succeeds; therefore, for recognizing the activities and their correct realizations, we propose to consider the activities as a sort of fuzzy temporal concepts that can be formalized as a multivariable function. Perceiving the world, an Activity Recognition System makes hypotheses and concepts about the observations. These hypotheses are resumed in a smoothing line and at the recognition time, the activities functions check how much the observations are close to their smoothing line. Finally, the activities are ranked based on the inferred similarities to the observations. All the introduced processes are data-driven and a case study that deals with recognition of simultaneous activities based on the proposed modeling approach is presented.**

Keywords- fuzzy logic; temporal data mining; smoothing; activity recognition

I. INTRODUCTION

Recently proposed works on activity recognition show effective but *unreliable* results. They are still dependent on the expert's knowledge in both learning and recognition steps; on one hand they presume activities are realized in ambient environment, but on the other hand they recognize each activity by consideration of only a few especial attributes. Therefore, they do not propose a totalitarian supervisor system that is capable to reason in all of the possible events that may occur every time and everywhere of the ambient environment. The result is that they cannot verify correct realization of activities.

One more major reason that made these approaches impractical is that their reasoning system is not flexible enough to handle existing uncertainty in input data; especially they are not capable to distinguish for what context, which inputs may play more important roles in activity recognition. In other words, they expect that the activities are performed in standard and rigid structures in order to be recognized.

In order to contribute in activity recognition, in the current work, we propose an approach that not only deals with data-driven activity recognition, but also proposes how to recognize correct realization of activities. Furthermore, we propose an extension of an event-driven approach, which is published in [2] and [9]. In that approach, we formalized an activity as a dynamic entity that can be recognized through recognitions of the fuzzy events caused by the activity realization (see Figure 1).

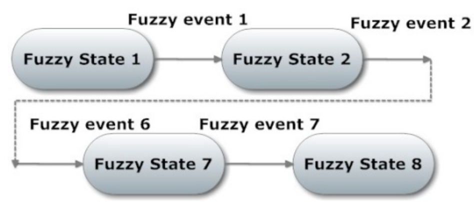

Figure 1. Activity of "coffee making" modeled as chain of fuzzy events

In order to perform a data-driven process to discover the fuzzy-events, we proposed to divide the world into two general parts, one of them representing the static characteristics of the activities (fuzzy context [12]) and the other representing the characteristics that dynamically change while the activities are realized (activities fuzzy states [13]). As a consequence, it is proposed to perform classification process to group the common fuzzy states of all activities in order to provide shortly all the learnt knowledge in a decision tree format. By this modeling approach, we could estimate the intention of the resident and predict the events that may occur in the future when a few elementary actions of a known plan or activity are seen [9].

The mentioned approach includes some limitations that are the subject of the current work: (i) The reasoning in recognition of activities can be done only when an action is performed in the world, so it does not reason in normality of the current momentum observations. Therefore, we desire the ability to do real-time reasoning. (ii) If more than one activity is realized (simultaneous activities), it does not recognize these correct activities as the normal world states. Moreover, interruption of activities cannot be surveyed.

In this paper, we propose to consider the activities as fuzzy temporal concepts that can be formalized as

 ISBN: 978-1-61208-282-0

multivariable mathematical problems such as the following equation:

$$y = \alpha_1 \tilde{x}_1^{\beta_1} + \alpha_2 \tilde{x}_2^{\beta_2} + \ldots + \alpha_n \tilde{x}_n^{\beta_n} \qquad (1)$$

Here, “y” represents the activity function, “x” represents the variable that activity depends on, and “α” and “β” are the variables’ factors in activity model. In order to achieve this model, we calculate the fuzzy contexts of the activities, then, the hypotheses around the observations taken from the activities realizations are generated and formalized as the fuzzy states of the activity. Each fuzzy state is represented with a fuzzy cluster center. In the next step, by performing smoothing techniques, all the mentioned fuzzy cluster centers are traversed through a line or curve in order to collect all possible activity states so that we calculate the activity’s function (“y”).

The reasoning for activity recognition will be done based on the discovered similarity between the observation and the activity formula. Then, the activities are ranked based on the inferred similarities to the observations. For instance, in Table I, we have illustrated twenty observations from a typical activity through six sensors (activity’s variables), in which one of them is time and the other ones are the distances of the objects to special points in the environments.

TABLE I. OBSERVATION OF THE SIX WORLD ATTRIBUTES IN TWENTY STAGES (SYNTHETIC DATA)

observation number	Variable 1	Variable 2	Variable 3	Variable 4	Variable 5	Variable 6
1	1	1	1	10	12	10
2	2	1	2	9	11	10
3	3	1	1	4	10	10
4	4	4	2	10	9	10
5	5	4	7	19	8	10
6	6	4	8	7	8	10
7	7	7	7	7	9	10
8	8	7	8	5	10	10
9	9	7	12	17	11	10
10	10	9	13	18	12	10
11	11	9	12	20	12	10
12	12	9	14	18	11	10
13	13	20	20	2	10	10
14	14	20	19	5	9	10
15	15	20	18	2	8	10
16	16	16	19	19	11	10
17	17	16	15	14	10	10
18	18	16	14	12	9	10
19	19	12	15	5	9	10
20	20	12	13	1	8	10

In order to break the world observations into two groups of context and activity states, we apply the subtractive clustering method [3]. The cluster estimation process is performed based on the similarities discovered between the data points. In Table II, we illustrated how the world is perceived. We presented several hypotheses in order to explain the observations if different cluster sizes (Influence Range) are desired. For example, one hypothesis is that activity transits four fuzzy states (coded as 3-1, 3-2, 3-3, 3-4 in Table II) and the sixth variable indicates the fuzzy context of this activity (symbolized by © in Table II).

TABLE II. SOME POSSIBLE HYPOTHESES AROUND THE OBSERVATIONS

Fuzzy State Number	Variable 1	Variable 2	Variable 3	Variable 4	Variable 5	Variable 6	Influence Range
1_1	8.0 ©	7.0 ©	8.0 ©	5.0 ©	10.0 ©	10.0 ©	IR=2
2_1	7.0	7.0	7.0	7.0	9.0	10.0 ©	IR=1.5
2_2	17.0	16.0	15.0	14.0	10.0	10.0 ©	IR=1.5
3_1	12.0	9.0	14.0	18.0	11.0	10.0 ©	IR=1
3_2	7.0	7.0	7.0	7.0	9.0	10.0 ©	IR=1
3_3	14.0	20.0	19.0	5.0	9.0	10.0 ©	IR=1
3_4	2.0	1.0	2.0	9.0	11.0	10.0 ©	IR=1
4_1	12.0	9.0	14.0	18.0	11.0	10.0 ©	IR=0.9
4_2	7.0	7.0	7.0	7.0	9.0	10.0 ©	IR=0.9
4_3	14.0	20.0	19.0	5.0	9.0	10.0 ©	IR=0.9
4_4	2.0	1.0	2.0	9.0	11.0	10.0 ©	IR=0.9
4_5	20.0	12.0	13.0	1.0	8.0	10.0 ©	IR=0.9
5_1	12.0	9.0	14.0	18.0	11.0	10.0 ©	IR=0.8
5_2	7.0	7.0	7.0	7.0	9.0	10.0 ©	IR=0.8
5_3	14.0	20.0	19.0	5.0	9.0	10.0 ©	IR=0.8
5_4	2.0	1.0	2.0	9.0	11.0	10.0 ©	IR=0.8
5_5	20.0	12.0	13.0	1.0	8.0	10.0 ©	IR=0.8
5_6	5.0	4.0	7.0	19.0	8.0	10.0 ©	IR=0.8
6_1	10.0	9.0	13.0	18.0	12.0	10.0 ©	IR=0.7
6_2	7.0	7.0	7.0	7.0	9.0	10.0 ©	IR=0.7
6_3	14.0	20.0	19.0	5.0	9.0	10.0 ©	IR=0.7
6_4	2.0	1.0	2.0	9.0	11.0	10.0 ©	IR=0.7
6_5	17.0	16.0	15.0	14.0	10.0	10.0 ©	IR=0.7
6_6	20.0	12.0	13.0	1.0	8.0	10.0 ©	IR=0.7
6_7	5.0	4.0	7.0	19.0	8.0	10.0 ©	IR=0.7
7_1	10.0	9.0	13.0	18.0	12.0	10.0 ©	IR=0.5
7_2	7.0	7.0	7.0	7.0	9.0	10.0 ©	IR=0.5
7_3	14.0	20.0	19.0	5.0	9.0	10.0 ©	IR=0.5
7_4	2.0	1.0	2.0	9.0	11.0	10.0 ©	IR=0.5
7_5	17.0	16.0	15.0	14.0	10.0	10.0 ©	IR=0.5
7_6	20.0	12.0	13.0	1.0	8.0	10.0 ©	IR=0.5
7_7	5.0	4.0	7.0	19.0	8.0	10.0 ©	IR=0.5
7_8	16.0	16.0	19.0	19.0	11.0	10.0 ©	IR=0.5
7_9	19.0	12.0	15.0	5.0	9.0	10.0 ©	IR=0.5
7_10	3.0	1.0	1.0	4.0	10.0	10.0 ©	IR=0.5
7_11	4.0	4.0	2.0	10.0	9.0	10.0 ©	IR=0.5
8_1	10.0	9.0	13.0	18.0	12.0	10.0 ©	IR=0.4
8_2	7.0	7.0	7.0	7.0	9.0	10.0 ©	IR=0.4
8_3	2.0	1.0	2.0	9.0	11.0	10.0 ©	IR=0.4
8_4	14.0	20.0	19.0	5.0	9.0	10.0 ©	IR=0.4
8_5	17.0	16.0	15.0	14.0	10.0	10.0 ©	IR=0.4
8_6	20.0	12.0	13.0	1.0	8.0	10.0 ©	IR=0.4
8_7	5.0	4.0	7.0	19.0	8.0	10.0 ©	IR=0.4
8_8	12.0	9.0	14.0	18.0	11.0	10.0 ©	IR=0.4
8_9	16.0	16.0	19.0	19.0	11.0	10.0 ©	IR=0.4
8_10	4.0	4.0	2.0	10.0	9.0	10.0 ©	IR=0.4
8_11	19.0	12.0	15.0	5.0	9.0	10.0 ©	IR=0.4
8_12	3.0	1.0	1.0	4.0	10.0	10.0 ©	IR=0.4
8_13	13.0	20.0	20.0	2.0	10.0	10.0 ©	IR=0.4
8_14	15.0	20.0	18.0	2.0	8.0	10.0 ©	IR=0.4
8_15	1.0	1.0	1.0	10.0	12.0	10.0 ©	IR=0.4
8_16	6.0	4.0	8.0	7.0	8.0	10.0 ©	IR=0.4
8_17	18.0	16.0	14.0	12.0	9.0	10.0 ©	IR=0.4
8_18	8.0	7.0	8.0	5.0	10.0	10.0 ©	IR=0.4

Each cluster can be represented by a cluster center. Therefore, instead of direct consideration of the observations in modeling process, we can take the explanative hypotheses (cluster centers). At the next step, we will calculate a function that represents the behavior of the sensors (variables) during the activity’s realization through a smoothing process. Finally, a function representing the activities characteristics is estimated.

The paper is organized as follows. Section II presents some preliminary theories about the proposed approach and justifies the choice of multivariable learning. Section III describes the formalizations and definitions concerning this framework which serves as foundation for modeling the recognition process. Section IV explains the process to estimate the activity function as an important step for recognition. Section V presents our method to survey the simultaneous activities by using the estimation of the

 ISBN: 978-1-61208-282-0

activity function model. In Section VI, a case study is presented in order to show experimental results and validation of the proposed approach. Finally, Section VII concludes the paper and outlines the future developments of this work.

II. ACTIVITY AS A FUZZY CONCEPTUAL SYSTEM

In this paper, we regard the "activity" as a type of *fuzzy dynamic conceptual system*. In fact, it is presumed that an intelligent system directs realization of the activity concepts in the virtual world of temporal datasets. In order to explain better this viewpoint we refer to the system theory [14], where, a system is defined as a set of interrelated objects that collaborate together in order to achieve a goal. A system has a boundary with its environment. It takes input from its environment, it processes it, it gives output to its environment, and it directs this output according to the taken feedback from the environment. For a system, we can imagine machine states and a hierarchy of subsystems. Here, the term "*conceptual system*" refers to a system that is composed of non-physical entities, i.e., ideas or concepts and concept is an abstract idea or a mental symbol, typically associated with a corresponding representation in language or symbology [15]. In conclusion, a conceptual system is simply a conceptual model [16].

An activity is a conceptual system because it respects the systems' specifications: (i) it consists of a set of interrelated variables which represent the world attributes, especially, the object's locations; (ii) it is realized to achieve a goal (especially the world state); (iii) it has a boundary with its environment, which is defined through fuzzy state and fuzzy context; (iv) it takes input from its environment by performing observation, it processes it, and it gives output to its environment by accomplishing an action in order to change the world attribute. For an activity we can define fuzzy states [13] and a hierarchy of concepts such as actions [4]. An activity is a dynamic conceptual system because its state depends on time [16] and since fuzzy set operators are applied to model it, an activity is regarded as a sort of *fuzzy dynamic conceptual system*.

A. *Fuzzy contexts of the activities*

Contexts are the surrounding conditions where activities are realized [12]. The fuzzy context refers to a set of variables in which they would keep a stable interrelation while the activities are realized. At the recognition time, any change in the context is interpreted as abnormality of the world state. For example, if a human wakes up at 6 o'clock, then it indicates a normal world state for the activity recognition problem, but if he wakes up at 2 PM, then it can be inferred that he is sick and there is an anomaly.

One other benefit of the consideration of contexts is that it helps with the identification of similar activities. When similar activities are performed in different contexts, they represent different concepts and in this way we can distinguish these different concepts. For example, if a human eats in the morning, it means that he is having his "breakfast", but the same activity (eating) at 12 o'clock means that he is having "lunch". In the next part we will deal with formalization of the fuzzy context.

In our view, context is a fuzzy term and it can be applied to multi-variable problems such as ambient environments, where multiple features of scenarios are observed. In the real world problems, any sensor data may vary (even partially) while the activities are realized. Sometimes these changes should be taken into account because this variation could be significant, but sometimes they should not be taken into account because the variations of sensor data are not significant to recognize the activity. We apply a fuzzy logic based clustering approach in order to survey different levels of details of occurring events in different levels of certainty and survey the activity models in their own contexts. The benefit of fuzzy context estimation is that it reduces the process complexity and focuses the calculations of the modeling on the role-playing variables.

B. *Fuzzy states of the activities*

Fuzzy state represents a general and brief description about the current status of the world. When an activity is realized, the world would transit a chain of fuzzy states (see Table II). However, this transition would be done in a special fuzzy context. Each activity is regarded as a sequence of fuzzy states (see Figure 1). In fact, when an activity is performed, the world would transit a chain of fuzzy states and the system achieves its goal while the activities are realized.

An intelligent system is assigned to direct the realization of an activity. Then, the perception of fuzzy states and fuzzy contexts would indicate how to repeat realization of this activity. For this system, the fuzzy context represents the system environmental and external conditions for realization of the activity, but the fuzzy states represent the procedures or the actions that should be performed by the system in order to realize the activity. In fact, the fuzzy states represent the internal states of this system and the events that would occur inside this system (see Figure 2).

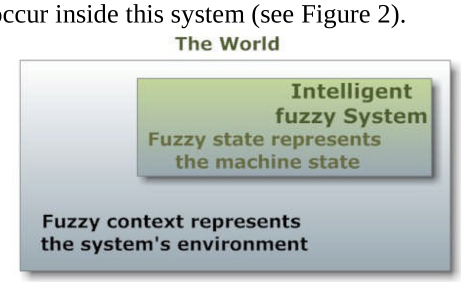

Figure 2. Fuzzy state and fuzzy context for realization of an activity

In Figure 2, we can see that although the types of the fuzzy contexts and fuzzy states are similar, the objective of their consideration is different. In fact, one represents the conditions for a scenario to be realized by an intelligent system, and the other represents the way that the scenario can be realized in the world. Therefore, it is presumed that in order to realize an activity the world is divided into two sections, which are system intern and system extern. The world features that should be unvaried during the activity realization are considered as the fuzzy context members and the attributes that would be varied (played) for activity realization would be taken into account as the fuzzy state elements. The boundary between a system intern and system extern is not a fixed, stable or definitive border. This logical boundary can dynamically change and new attributes can join the system environment (fuzzy context) after a few steps in activity completion.

III. FORMALIZATIONS

Here, we introduce a modeling process to learn the activities. The main function of activity modeling is to recognize them and to reason in the correct realization of the activities. Moreover, we would be able to judge if the world state is normal, or if the smart home resident needs assistance [10].

The "world" of the proposed learning problem is observed through a set of applied sensors "S". "s_i" represents sensor "i" from the set of applied sensors; "n" refers to the number of sensors or variables and "a" refers to a typical activity. Goal "G" is achieved when "a" is realized, so, in rather most of the cases, we can imagine that a goal achievement is equivalent to an activity realization. Presuming that the reality is the state of the world attributes as they actually are, the world is the collection of attributes that are observed from the world accompanying their observed values. In ambient environment the world is observed through a set of embedded sensors "S" where "s_i" observes the i'th attribute of the real world out of the "n" observed features. We refer to "s_i" at time "t" by "$v_{i,t}$"; "T" is the number of times that observation is done.

Definition 3.1 (*world*). The virtual world is formalized as set $World = \{(s_i, t, v_{i,t}) \mid (s_i, t, v_{i,t}) \in S \times \Re \oplus \{0,1\} \times T, |S| = n, v_{i,t} = val(s_i, t)\}$

where "s_i" is the i'th sensor of the observing sensor, the *val()* function captures the value of the sensor "s_i" at time $t \in T$. The observations are done through "n" sensors for "T" times. RFID sensors or generally, any kind or sensors that generate any amount of values $v \in \Re$ or the ones that generate 0-1 values are the data types that are accepted.

Because activities are realized and observed in an ambient environment, we expect the observed world is affected by no event occurring out of the ambient environment. Moreover, we presume that all possible world states are observed within "T" observations. Therefore, in this paper, the Activity Recognition Reasoning System (ARRS) supposes the world is closed or in other words it benefits from the Closed World Assumption (CWA), which is a presumption that what is not currently known to be true is false [17]. So, it is presumed that if no explanation for an observation is found, then we infer that the world is abnormal or an erroneous activity is realized.

Definition 3.2 (*momentum observation*). This is the set of digitized numeric values taken from each sensor and registered into a temporal dataset, which indicates the world quality at once. In other words, an observation is a line of data-record inside of a temporal dataset which registers frequently the measured world qualities. It is presumed that per observation, the world attributes are observed simultaneously and synchronously, so that at a record of observation we can find all the measured attributes refering to a unique world state. For example, we will not have the world temperature at time 12:00 with the world light at time 13:00 within a single data record. That is to say every attribute of an observation refers to a single reality or each attribute explains a property of a single object (observation)

A temporal dataset would indicate a set of observations. If the observations concern an activity realization then a temporal dataset consisting from multi-attribute observations is formed. We represent the set of observations in a matrix format, where the consisting elements are the values that indicate the quantified world's qualities. It may be sorted by a world attribute such as time:

$$O_{S,G} = \begin{bmatrix} v_{11} & \cdots & v_{1n} \\ \vdots & \ddots & \vdots \\ v_{T1} & \cdots & v_{Tn} \end{bmatrix}$$

Definition 3.3 (*variable state*). Each variable of the observation matrix represents a value concerning an observed world attribute or an activity feature. This value is given to the variable according to the measurement that a sensor does from the concerning attribute.

For example, in Table I, in each column we can see twenty states per each variable. Here, a set of variable state is defined as the values that a sensor generates. The important point in here is that the definition of a variable or sensor state is dependent on the time, so by elapse of time new data records are created and new variables states can be created. Considering the role of time, we face two groups of variable states. The first group of states refers to the values that in several moments the variable stops and causes a relatively ***stable*** state within that value. For the other group, there are also ***transition*** states that demonstrate transition of a variable from a stable state to other stable states. In order to distinguish these two *transition* and *stable* states in a data-driven manner, we consider the time factor, so when a variable stays at a definitive value for a *relatively long* time, then this value is a sensor (variable) state and if a variable stays *relatively short* on a definitive value, then it is a

 ISBN: 978-1-61208-282-0

transition state. In this paper, by the world state we refer to the stable state

$$State_i = \{v_{ti} \in O_a : \exists \mathcal{E} \in [1,T],\ i \in [1,n] \rightarrow v_{t-\mathcal{E}i} = v_{ti} = v_{t+\mathcal{E}i}\}.$$

Here, "Ɛ" is the minimum delay for stay of a value in order to be recognized as a stable state. In the following parts of this paper when we talk about variable state, we refer to the stable variable state.

For each action that a smart home resident performs (in order to complete realization of an activity), the state of one or more sensors may be actuated, so their monitoring digital numeric value may be changed. Therefore, the accomplishment of simple actions in smart home is mapped as a *time series* of events in the temporal datasets. During the realization of activities, we can see each sensor stay *temporary* or *permanently* at definitive values. This stability at definitive values causes consideration of a world state.

Definition 3.4 (*world state*). Each record of the observation matrix represents a schema concerning an observed world. We define the variable state as a set $world\ state = \{V_{i,t} \mid V_{i,t} \in O_{S,G}.t\ and\ \vee i \rightarrow V_{i,t} = V_{i,t+1} = V_{i,t+2} = \ldots = V_{i,t+\varepsilon}\}$ in which "t" refers to the time of observation and indicates all observed attributes at time "t".

World state represents a short estimation from the world quality. The world quality is estimated depending on the observed attributes. If more attributes from the world are observed, then a better estimation from the world state is provided and the difference between similar world states is better distinguishable. For example, in Table II, considering the world is observed frequently, each record of the gathered temporal data represents an instantaneous estimation from the world quality. In other words, each record of the observation matrix represents a momentum world state at the concerning moment.

The important point here is that the definition of world state is dependent on the time, so by the lapse of time new data records are created and new world states can be created. Considering the role of time, we face two main groups of world states. The first sort of states refers to the moments that entire variables stop in their old values and cause a relatively ***stable*** world state. There are also ***transition*** states that demonstrate transition of a world state from a stable state to other stable states. In order to distinguish these two *transition* and *stable* states in a data-driven manner, we consider the time factor, so when the world stays at a definitive sets of values for a *relatively long* time then it causes a world state and if the world stays *relatively short* on a definitive sets of values then it is a transition state.

In the following parts of this paper when we talk about "world state" or "home state", we refer to the stable world state. With the exception of the expression of the world state per *moment of observation*, there are several other ways to express the world states; we can view the world regarding other variables' states in order to estimate the world state. For example, we can view the world represented in Table II by this expression:

"The world state in which the distance of sugar to RFID antenna 2 is high and the distance of glass to the RFID antenna 2 is high."

In this statement, we pointed out to the second and fourth record of the observation matrix. Therefore, world state is a record or a group of records from the observation matrix which are subjected to variable limitations.

Definition 3.5 (*cluster center*). It is a set of observations representing groups of observations that are similar to each other $CC_{i,t} = subtract(O_{i,t})$, where "$CC_{i,t}$" are the cluster centers that represent their own group of similar data points.

In temporal subtractive clustering process, the cluster centers are discovered based on two parameters: (i) the first one is a cluster of similar observations of a single sensor. For each cluster (containing similar data points), a cluster center is discovered in order to represent its concerning cluster members; (ii) the second one is a cluster of similar momentum observations, which are a row in "$O_{i,t}$". For each cluster (containing similar observations), a n-dimensional cluster center is discovered in order to represent its concerning cluster members. The symbol "n" represents the number of observing sensors or the variables: {1<i<n}. For detailed information about the cluster center estimation using subtractive clustering approach, which is not the main focus of this work, please refer to [3]. Through the process of cluster center estimation we can calculate the fuzzy sensors state and fuzzy world state.

Definition 3.6 (*fuzzy sensor state*). It is a set of observations concerning a single sensor, which represent a group of similar observations series

$$\tilde{S}_i = \{(\tilde{v}_i, \tilde{t}) \in O_{S,G} \times T,\ s_i \in S,\ \tilde{v}_i = CC_{it}.v_i,\ \tilde{t} = CC_{it}.t, 0 \le IR \le 1\}$$

, in which a sensor state is simply indicated as a couple combined from value and time representing the cluster members.

One important point here is that the selection of different influence ranges in cluster center estimation would lead to different interpretations from the sensor observations; so, different data points with different quantity of the cluster centers are proposed as the sensor states. In order to take this parameter into account and point to a special sensor state, we would have:

$$\tilde{S}_{a,i,IR,k} = \{(\tilde{V}_i, \tilde{t}) \mid (\tilde{V}_i, \tilde{t}) \in O_{S,G=a},$$
$$i = 1,2,...,n, s_i \in S, \tilde{V}_i = CC_{i,t}.V_i,$$
$$\tilde{t} = CC_{i,t}.t, 0 \le IR \le 1, k \in \mathbb{N}, 1 \le k \le T\}$$

In here, "a" refers to the activity that is realized to achieve the goal "G", IR is the desired detail/generality from the data and "k" points to k'th cluster center ordered by $\tilde{t}$. "IR" is the influence range or the cluster radius rate, which defines the clusters' sizes; therefore, the cluster centers would represent similar data points, where the similarity criterion is the cluster radius. Influence range factor is a relative factor and it depends on the range of the data points. It should be mentioned that depending on the cluster radius, different cluster centers may be discovered. Therefore, for each temporal dataset, different sets of data records representing the total dataset may be discovered.

In the next part we will discuss that combinations of fuzzy sensors' states would lead to creation of fuzzy world states.

Definition 3.7 (*fuzzy world state*). It is a set of observations concerning all applied sensors, which represents one group of similar observations. It represents an approximate evaluation of a world state and during this state the world is seen as stable. Fuzzy state is formed from groups of similar world states. It is calculated as a result of comparison process between all of the world states and it is indicated to other world states.

The formalization of the fuzzy state is presented in the following:

$$FS_{a,IR,k} = \{(s_i, \tilde{v}_i, \tilde{t}) \mid i = 1,2,..,n,$$
$$s_i \in S, \tilde{V}_i \in O_{S,G=a}, \tilde{V}_i = CC_{i,t}.V_i,$$
$$\tilde{t} = CC_{i,t}.t, 0 \le IR \le 1, 1 \le k \le T\}$$

where "a" refers to the followed activity; "IR" refers to the range of influence or the relative similarity degree, and "k" refers to the k'th (out of "T" possible fuzzy classes) data point that absorbs similar data points around at the influence range of IR; "k" also represents the number of fuzzy states that are transited, so that activity "a" is realized. A fuzzy state may include (subsume) one or more rows of the $O_{S,G}$ matrix. For example, on the data of the Table I we can apply fuzzy clustering process on the data points in order to extract the points (cluster centers) that the data is concentrated around them, so they represent different existing qualities of the data points, which are similar to the majority of the data points. The result of this process is demonstrated in Table II. In there, we have shown that if at cluster radius is selected as IR =0.7, then the world would be divided into seven fuzzy states. If at running time a relatively high similarity between the current observations and the learned fuzzy cluster centers is observed, then it can be inferred that the observations may belong to realization of the surveyed activity.

Definition 3.8 (*fuzzy activity*). It is a set of observations concerning all applied sensors, which represents groups of similar observations. It represents an approximate evaluation from the fuzzy world states that are transited when an activity is realized.

The fuzzy activity is formalized as a set $FA_{a,IR} = \{(s_i, \tilde{v}_i, \tilde{t}): s_i \in S,\ \tilde{v}_i = CC_{it}.v_i \in O_{S,G=a}, \tilde{t} = CC_{it}.t, 0 \le IR \le 1, t.count = m\}$, where "a" refers to the followed activity; "IR" refers to the considered range of influence or the relative similarity degree, and "m" refers to the number of fuzzy states that the world is transited in realization of "a", so we have: $0 \le k \le m \le T$ and $FS_{a,IR,k} \subseteq FA_{a,IR}$.

In order to calculate the "$FA_{a,IR}$" in matrix format, we perform the subtractive clustering process on the observations matrix:

$$FA_{a,IR} = subtract(O_{S,G}) = subtract(O_{S,G}) = \overbrace{\begin{bmatrix} \tilde{t}_1 & CC_{1,1} & . & . & . & . \\ . & . & . & . & . & . \\ \tilde{t}_k & . & . & CC_{i,k} & . & . \\ . & . & . & . & . & . \\ \tilde{t}_m & . & . & . & . & CC_{n,m} \end{bmatrix}}^{S_i} \begin{matrix} \rightarrow FS_{a,IR,1} \\ \\ \rightarrow FS_{a,IR,k} \\ \\ \rightarrow FS_{a,IR,m} \end{matrix}$$

"$FA_{a,IR}$" represents the points (cluster centers) that each variable (data of a column) regarding to itself or regarding to other variables (data of other columns) would have a meaningful concentration around. Each row of the "$FA_{a,IR}$" matrix is in fact a fuzzy world state. In this definition, 'n' is the number of columns (variables or sensors), then it can be inferred that activity "a" would 'm' times change the world state to achieve the goal "G".

Definition 3.9 (*Fuzzy context*). Fuzzy context is referred to as "$\tilde{C}$" and it is the set of variables that do not play any significant role in both realization and recognition of the activity "a" such as $\tilde{C}_{a,IR} = \{(s_i, \tilde{v}_i): s_i \in S, \tilde{v}_i \in O_{S,G=a}, \forall t \in [1,T] \rightarrow v_i \approx \tilde{v}_i\}$.

The variable "s_i" during the time of the activity "a" realization does not vary significantly and it is fixed to value "$\tilde{v}_i$"; this value is calculated through the cluster center discovery process. Fuzzy context indicates the surrounding circumstances that scenarios or activities are realized in. The fuzzy contexts of the activities indicate the conditions in which the activities models are valid. A change in the fuzzy context may cause invalidity of the system's perception of the activities; so, it will be taken into account as a new activity model. Therefore, any knowledge extracted from the observations is valid only if the similar context is met.

IV. ACTIVITY FUNCTION ESTIMATION

As it was mentioned earlier, one of our contributions in this paper is to propose a multivariable function in order to recognize it. The goal of this function is to recognize the activities and in order to do that, it transfers the observations to the model space, which is the activity space. This function is represented by "y_a", in which "a" refers to the surveyed activity. For instance, if we consider the positions of the "glass" and "sugar" objects in realization of the "coffee making" activity, then the "$y_{\text{coffee making}}$" transfers the observations of the concerning sensors to the activity space in order to verify how much it is similar to the coffee making activity (see Figure 3).

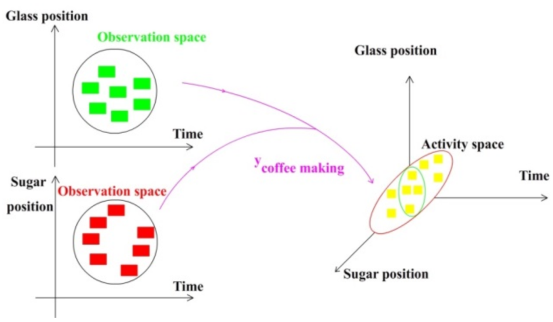

Figure 3. Activity function

The way that this function works is based on the discovered similarities between observations and the activity structure. Therefore, it is expected that this function reasons in both momentum observations and the series of observations to recognize the ongoing activity. In order to discover this function, we calculate equivalent of a curve or a line that traverses the activities' cluster centers. When an observation is recognized as similar to at least one of the activity's fuzzy state, then it can be inferred that it may possibly justify the realization of the activity. The sensors are the variables that the activity function depends on and based on their generated numerical values we can model or recognize the activities. Presuming that we intend to calculate a ***line*** that traverses the cluster centers of the Fuzzy Activity (FA), the resultant line is reported in the following equation:

$$y_a = \alpha_1 s_1 + \alpha_2 s_2 + \ldots + \alpha_n s_n + \alpha_0 \tag{2}$$

Here, "y_a" indicates the similarity degree to the activity model and "a" is the activity.

A. Sensor data smoothing

Dataset smoothing is a creation of an approximating function that attempts to capture important patterns in the data points [18]. The resultant smoothing line, traverses normally the data points otherwise it passes near with relatively closed distance. In the case that the smoothed values can be written as a linear transformation of the observed values, the smoothing operation is known as a linear smoother; the matrix representing the transformation is known as a "smoother" matrix or hat matrix.

There are several ways to smooth the data points and each of them can be customized according to the problem. Here, we suffice to introduce some famous smoothing methods, which are moving average, Local regression using weighted linear least squares with a polynomial model, Savitzky-Golay filter, and Kalman filtering [19]. Generally, these methods are different in the way they treat the existing noise of the data and in the linearity of the smoothing curve. For example, in Figure 4, it is graphically illustrated how a smoothing line resumes the observations of a sensor (location of the glass) using a linear smoother.

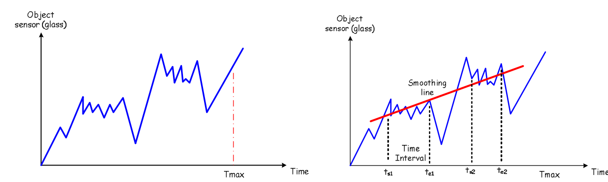

Figure 4. Smoothing of the sensors' observations

In Figure 4, we have presented that the sensors observations can be described by a line calculated by a linear smoothing technique such as linear regression [20].

B. Temporal behavior of the sensors

Behavior of the sensors in realization of the activities can be estimated and model through application of smoothing technique.

Definition 4.1 (*Sensor's linear Temporal Behavior*). Applying linear regression, we can calculate the sensors' data trend while the activity "a" is realized. Performing this process, the observations of the sensor "i" will be calculated in the following equation:

$$\overline{s}_{a,i,t} = \beta_{j,i} t + \tau_{j,i} \tag{3}$$

Here, $\overline{s}_{a,i,t}$ represents the average value of the "s_i" at time "t" in realization of activity "a". "β" and "τ" are the smoothing line factors calculated from the linear smoothing process obtained by the equation:

$$\beta_i = \frac{1}{T}\sum_{t=1}^{T} v_{i,t}.t, \ \ \tau_i = v_{i,t} - \beta_i \tag{4}$$

The calculations are done per each activity in the set of activities "A". The "T" is the activity duration. Because there are several smoothing methods and for each method different factors for data trend are proposed, from here, we refer to the "β" and "τ" by the term "smoothing factors".

 ISBN: 978-1-61208-282-0

Each sensor during different activities may present different behavior. Therefore, by verifying the sensors' behaviors, we can find which activity is the most possible ongoing activity. Matrix containing all the sensors' smoothing factors in realizations of all activities is estimated by the equation:

$$\gamma = \left[\beta_{j,i}\right].s_i + \left[\tau_{j,i}\right] \tag{5}$$

The symbol "j" refers to the j'th activity out of "m" activities and "γ" represents the matrix of activities. In order to recognize an activity, the current (live) observations are compared to the "γ" and the activities are ranked from small to big deviations to the sensors' temporal behaviors in order to explain the current observations.

C. Integrating temporal behaviors of the sensors in activities realizations

Behavior of all sensors in realization of the activities can be integrated and modeled through a curve or line that traverses the fuzzy states of the activities (which are multidimensional data points).

Definition 4.2 (*Activities Linear Temporal Behavior*). It is the collection of data points representing the behavior of the sensors per each activity in smart home. This matrix is represented by "γ" and for the recognition objectives, the most similar behavior would be inferred as the most possible ongoing activity. This concept is formalized as set where "a_j" refers to the j'th activity of the set "A".

$$\gamma = \{x_j \mid x_j \in \overline{s}_{a_j,i,t}, a_j \in A,\ j = 1,2,...,m,$$
$$i = 1,2,...,n,\ t = 1,2,...,T\}$$

In order to apply the "γ" matrix for activity recognition, we would calculate the distance of the current (live) observations. Out of the "m" activities, the one which tells the most similarity in activity trend will be selected as the most possible ongoing activity. The activities may be sorted according to this criterion. In order to calculate the similarity distance between a typical data point ("$v_{i,t}$") and a sensor trend line, we would apply the following equation:

$$d_{a,i,t} = \frac{\left|(v_{i,t}.\overline{s}_{a,i,t}) - (t.\beta_{j,i}t) - \tau_{j,i}\right|}{\sqrt{(\beta_{j,i})^2 + (\tau_{j,i})^2}} \tag{6}$$

In this formula, "$d_{a,i,t}$" is the Euclidian distance of the point ("$v_{i,t}$") to the activity trend line and it represents the similarity measure of the mentioned point to the sensor's behavior in realization of the activity "a". Generally, each sensor can generate numerical values in range from its max to min. Therefore, max ("d_i") and min ("d_i") are the values that may be calculated manually or by the expert's idea. Therefore, we can normalize the similarities using this equation:

$$Nd_{a,i,t} = \frac{d_{a,i,t}}{\max(d_i)}, \tag{7}$$
$$\min(d_i) \le d_{a,i,t} \le \max(d_i)$$

In order to take similarity between the observation and the total activity trend, we may apply several methods in order to calculate the similarity degree. In here, because our objective is to demonstrate only a general schema from this process, we would suffice to the average similarity method given by the following equation:

$$\pi(v_{i,t} \in a) = \frac{\sum_{i=1}^{n} \frac{1}{Nd_{a,i,t}}}{n} \tag{8}$$

Here, the "y_a" refers to the possibility that "$v_{i,t}$" belongs to realization of the goal "a". In order to recognize the activities at a glance and to calculate the *linear activity multivariable function*, we can perform a multiple regression on the output and input of the activity's formula given by the following equation:

$$y_a = \ regression\ \left(\frac{\sum_{i=1}^{n} \frac{1}{Nd_{a,i,t}}}{n}, Nd_{a,i,t}.v_{i,t}\right) \tag{9}$$

The symbol "y_a" represents the activity function and it is resulted as the result of some linear operations on the observations.

In this section, we discussed that an activity may be recognized using linear statistical analysis methods. A big problem of the application of this method is that it does not help with the recognition of correct realization of an activity. If two or more activities are different in just a few actions (one or a few more sensors), they will not be recognizable because the calculation of their portion in similarity degree would not be noticeable,. Moreover, if an activity is realized fast or slowly, then it will cause noticeable differences in $\pi(v_{it} \in a)$. Experimentally, two different activities may cause very similar trends, so we cannot rely well on the results. The weight of every data point is equal; hence a noise may cause an undesirable high similarity degree. Finally, it can be mentioned that generally, calculation of the similarity degree would depend on three factors: quantity of the training data records or the time of activity realization, domain of the sensors' generated numerical values, and quantity of the observing sensors. In order to improve this method, we would perform the smoothing process on the fuzzy cluster centers of the activities. We calculate fuzzy states of the sensors and perform the smoothing on the cluster centers (see Figure 5). Some advantages of this process are that we would be able to eliminate the transition states and also eliminate the data points that point continuously to a repetitive point.

Moreover, the amount of the smoothing data points would be significantly decreased.

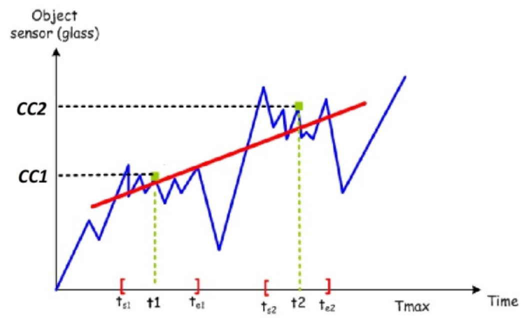

Figure 5. Smoothing fuzzy sensor states

In Figure 5, it is illustrated that the process of smoothing can be performed on the points that are the most similar to their neighbors. This way we can redirect the similarity degrees to the best representing data points rather than to probable noise or transition states; therefore, we can distinguish better the activities. In the next section we will discuss this issue.

V. SIMULTANEOUS ACTIVITIES

In order to realize an activity, several actions get accomplished simultaneously, which are directed by smart home resident. For each action, two more sensors may observe the consequences of the action; therefore, even a simple action can be interpreted as a set of simultaneous operations. For example, when an object is moved two sensors may observe this movement and two operations (in direction to each sensor) can result.

Using the set theory, we can combine or analyze the constituting elements of the concepts and as the result we can recognize high or low level concepts rather than individual activities. The application of this contribution is data-driven recognition of simultaneous activities and also lower-level concepts such as actions; therefore, we can reason for the activities interferences.

The recognition of simultaneous activities requires to analyze the fuzzy-world states in order to discover realization of which activities may possibly cause the world state. By using traditional set theory, we would apply the union (U) operation to find the constituting elements. When two singular activities (“a_k” and “a_u”) are realized together then we would have $FA_s=FA_{au}\cup FA_{ak}$ in which “FA_s” refers to the simultaneous activity. In here, we would treat the fuzzy entities (fuzzy clusters) with the traditional set theory. The result is analyze/combine of the learnt concepts. In order to analyze the “FA_s” based on the known activities we apply the set theory algebra, which indicates $FA_s=FA_{au}+FA_{ak}-(FA_{au}\cdot FA_{ak})$.

Therefore, “a_k” refers to the known activity and “a_u” refers to the unknown activity. A key point in here is that the fuzzy context of both activities should be respected in order for both activity models to be validated. Therefore, the resultant world state should be subjected to $\tilde{C}_{as}=\tilde{C}_{au}\cap\tilde{C}_{ak}$. .

Definition 5.1 (*simultaneous activities*). Simultaneous activities are the sequence of fuzzy events that follow achievement of two or more goals. Each fuzzy state concerning the realization of a social activity should be valid for both of the activity patterns. In other words, combination of individual activities is called simultaneous activities. The concept of “simultaneous activity” refers to the perception of the activities and the learned models from them. Regardless of the quantity of activity performers, when combination of two or more concepts is inferred, then a simultaneous activity is recognized. The simultaneous activity can be represented as $FA_s=FA_{au}\cup FA_{ak}$ subject to $\tilde{C}_{as}=\tilde{C}_{au}\cap\tilde{C}_{ak}$. Constraints of each of the running simultaneous activities should be realized in a space that satisfies all of the known goals. This space is made using fuzzy logic in a way that each activity saves its general structure and has partial flexibility if it faces the deviations from its previously learned structure.

VI. CASE STUDY

In order to validate the proposed approach, we implemented a series of activities in both singular and simultaneous manners in the LIARA laboratory [11]. More than 500 activity features were observed during realization of these activities. Singular realization of the coffee making and hand washing activity was modeled. The simultaneous realization of them was also modeled and we calculated the simultaneous realization of these singular realizations. We verified the similarity of these activities to their models and finally, in Figure 6 we have represented the inferred similarity in the range of [0-10].

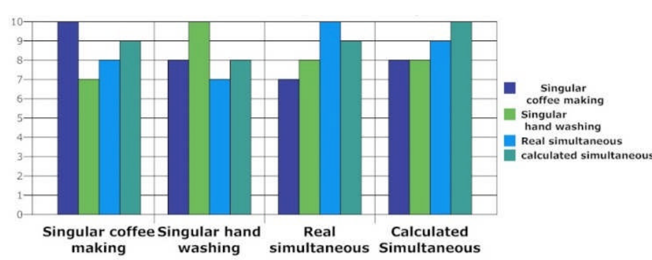

Figure 6. Similarity degrees in recognition of activities

In our experiments, we saw that the calculated simultaneous activity could approximately replace the real simultaneous model. Other experiments proposed in [10] confirmed reliable results, too. The important point here is that we could achieve this result through application of the activities multivariable function that could explain the activities’ dynamicity at a glance.

VII. CONCLUSION

In this paper, we discussed how to model the activities as multivariable problems and proposed to apply fuzzy logic, especially the fuzzy time concept in order to model the dynamicity of an activity in a mathematical function. This function draws a fuzzy space for realization of the activities. One benefit of this method is the modeling the simultaneous activities. On one hand, the uncertainty in human behavior is considered, and on the other hand, the imprecision of the sensors is handled. However, the current solution needs improvements. For example, the proposed approach learns the activity models at first. Then, it uses the learnt knowledge at the runtime. We did not propose an online learning technique because we cannot distinguish between anomaly and a new manner of correct activity realization. A possible solution for this limitation is to make a border and definition for tolerable anomalies, then any unfamiliar patterns, which do not cross that border could be taken into account as a new correct activity. This task would need new definition on normality.

REFERENCES

[1] L. A. Zadeh. Fuzzy Sets as a basis for a theory of possibility. Fuzzy Sets and Systems 1:3-28, 1978.

[2] F. Amirjavid, A. Bouzouane and B. Bouchard. Activity modeling under uncertainty by trace of objects in smart homes, Journal of Ambient Intelligence and Humanized Computing, Springer publisher, pp 1-16 (accepted as full paper), 2012.

[3] S.L. Chiu. An efficient method for extracting fuzzy classification rules from high dimensional data, Journal of Advanced Computational Intelligence, 1:31-36, 1997.

[4] P. Roy, B. Bouchard, A. Bouzouane and S. Giroux. A possibilistic approach for activity recognition in smart homes for cognitive assistance to Alzheimer's patient. In Activity Recognition in Pervasive Intelligent Environment (Atlantis Ambient and Pervasive Intelligence), L. Chen, C. Nugent, J. Biswas, J. Hoey Editors, World Scientific Publishing Company, ISBN: 978-9078677352, pp. 31-56, 2010.

[5] E. Nazerfard, P. Rashidi and D.J. Cook. Discovering temporal features and relations of activity patterns, Proceedings of the IEEE international conference on data mining workshops, pp. 1069-1075, 2010.

[6] T. Mitsa. Temporal data mining. Chapman & Hall, 2010.

[7] Information available at: www.mathworks.com, last time visited on 15 April 2013.

[8] J. Sowa. Conceptual Structures: Information Processing in Mind and Machine", Addison-Wesley, 1984.

[9] F. Amirjavid, A. Bouzouane and B. Bouchard, Tracing objects to retrieve prediction patterns of activities in smart homes, ICCS 2011, PP 1-5, Derby, 2011.

[10] F. Amirjavid, A. Bouzouane and B. Bouchard, Discovery of data-driven fuzzy conceptual structures for the activities, ICIS2013, PP 1-7, Japan, 2013.

[11] Information available at: www.liara.uqac.ca, last time visited on 15 April 2013.

[12] F. Amirjavid, A. Bouzouane, B. Bouchard; Recognition of fuzzy contexts of activities in a smart home , IEEE International Workshop on Data Integration and Mining (DIM-2012), IEEE publisher, August 8-10, Las Vegas, Nevada, USA pp 1-8 (accepted as full paper), 2012.

[13] F. Amirjavid, A. Bouzouane, B. Bouchard; Optimization of activities in smart homes , International Workshop on Data Mining in the Life Sciences (DMLS'12) , July 20, Berlin/ Germany, pp 1-8 (accepted as full paper), 2012.

[14] I. V. BLAUBERG, V. N. SADOVSKY, and E. G. YUDIN, Systems Theory: Philosophical and Methodological Problems: Progress Publishers, Moscow, 1977.

[15] F. Baader, D. Calvanese, D. L. McGuinness, D. Nardi, P. F. Patel-Schneider: The Description Logic Handbook: Theory, Implementation, Applications. Cambridge University Press, Cambridge, UK, 2003.

[16] A. Gemino, Y. Wand, A framework for empirical evaluation of conceptual modeling techniques, Springer-Verlag, London, Requirements Eng 9 (2004) pp. 248-260.

[17] M. Cadoli; Lenzerini, Maurizio, "The complexity of propositional closed world reasoning and circumscription". Journal of Computer and System Sciences, April 1994.

[18] J. S. Simonoff, Smoothing Methods in Statistics, 2nd edition. Springer ISBN 978-0387947167, 1998.

[19] J. Hamilton, Time Series Analysis, Princeton University Press. Chapter 13, 'The Kalman Filter', 1994.

[20] N.R. Draper, and H. Smith, Applied Regression Analysis Wiley Series in Probability and Statistics, 1998.

Trustful Interaction Between Intelligent Building Control and Energy Suppliers of the Smart Power Grid

Michael Massoth and Torsten Wiens
Department of Computer Science
Hochschule Darmstadt — University of Applied Sciences
{michael.massoth | torsten.wiens}@h-da.de

***Abstract*—This paper describes an approach to balance loads in smart power grids using a solution based on Next Generation Network (NGN) components, Smart Home appliances based on the KNX bus, and a secure and trustful interaction between intelligent home control managers and the energy suppliers of the smart power grid. The NGN components are applied as a communication and integration platform between the smartphone of the facility managers, the home automation and building control system, as well as the energy suppliers of the smart power grid. The Session Initiation Protocol (SIP) and the Presence Service are used to build a well performing and scalable system based on open source software. The idea is to publish data of actual power consumption and power reserves of selected Smart Home appliances by use of the Presence Service to the outside world. In a second step, the corresponding energy supplier could subscribe to this data of actual energy consumption and reserves. Based on this data, the energy supplier is enabled to send specialized offers towards the Smart Home owners reflecting possible benefits to the power grid. This solution respects the right to property and the right to self-determination of the Smart Home and facility control managers, because they have to agree to the energy management offer made by the energy supplier. It is a trustful solution because the relevant data could by easily pseudonymized before being published by the Presence Service. An approach to ensure secure communication against attackers from outside is presented and evaluated as well.**

Keywords—Home Automation; Smart Power Grid; Load Balancing, NGN, Presence Service.

I. INTRODUCTION

The current trend is to make the human environment smarter, using ubiquitous IT-technologies. This leads to smart cities, buildings, energy management, cars and phones. Every part of our environment will be connected to each other and can be controlled, with the given rights, from central points.

In such a world, security and trust are of essential importance. Confidentiality, integrity, availability and authenticity have to be given. In this paper, we describe the security of a remotely controllable KNX-based home and building control solution. The owner or facility manager of such a home can remotely monitor and control his house or facility wherever and whenever they like. A Smart Home shall enable interaction with its users, including the ability to monitor the status and control of building appliances and devices remotely from anywhere in the world. Such devices may consist of alarm systems, keyless access control, smoke detectors, light and heat control, medical devices, and all types of sensors (e.g., room, door, window or security surveillance, monitoring and control, statistics and remote metering).

A. *Purpose and Relevance*

The purpose of this paper is to present a new approach for a well performing, scalable, secure and trustful interaction between intelligent home control managers and the energy suppliers of the smart power grid. The novelty of the presented approach is to make use of an NGN Presence Service for the interaction between the smart home control and the energy supplier, and not only between the smart home and the house owner, as already described in [2,3,4]. The mobile ubiquitous home and facility control solution is based on SIP and the Presence Service. The described solution uses the advantages of a NGN to remotely monitor and control home automation systems via a mobile device using open source software.

The global carrier VoIP and IP Multimedia Subsystem (IMS) market for NGN-based services and infrastructures has reached US$ 658 million in the second quarter of 2012, according to Infonetics Research. Furthermore, the market drivers are intact and the numbers of VoIP and IMS subscribers are growing [1]. This forecast shows the business opportunity and relevance of the proposed solution for ubiquitous home control services.

B. *Structure of the Paper*

Following the introduction, Section II shows related work and other projects comparable to our solution. In Section III, the general concept is outlined and important use cases are presented. The overall system design is described in Section IV, differentiating three levels of interaction. The components used to build the system are presented in Section V. The security approach is discussed and evaluated in Section VI. Section VII describes the status of our prototype. Section VII concludes the paper and gives an outlook of future work.

II. RELATED WORK

Smart Home is not a new topic. Many companies and institutions are working on solutions for Smart Homes. But only a few are working on a complete solution that relies solely on open standards. Most systems focus on the inside (e.g., KNX) or outside (e.g., IP) system of the building only. This means that their goal is to build a solution either for the management of actors and sensors, or to develop a communication solution for existing bus systems.

In our previous work [2, 3, 4, 5], we created a signaling gateway between the KNX home automation and building control system [6] and SIP, allowing communication of mobile devices with KNX sensors/actors using existing SIP infrastructure. The idea of our solution was to connect the technology of NGNs to Smart Home Control Systems.

The HomeSIP project is a similar approach, allowing home control only using SIP [7, 8, 9]. The important parts of the system are the SIP proxy and the SIP sensor network gateways. The SIP proxy is the central component for communication. The sensor network gateways are embedded Linux systems, which are used to control the sensor networks and connect them to the SIP proxy. So, SIP is used for communication between the sensor networks, the SIP proxy and the mobile controlling devices, like smartphones. All information from and to the sensor networks is transported via SIP. The paper "Security for KNXnet/IP" [10] evaluates different approaches to grant security in an IP network, which is coupled to KNX. In contrast, we are using SIP as a bridge to the NGN world.

III. USE CASES OF SMART ENERGY MANAGEMENT

In this section, two typical business cases respectively use cases of smart energy management and electric load balancing and regulating are discussed.

A. *Use case (UC1): Surplus or excess of renewable energy*

Let us assume for use case (UC1) that the power consumption and load in the city reaches its lowest level. During the same time frame, the renewable energy is fed into the power grid at maximum because of strong winds or strong sun radiation. This surplus or excess of electric power shall be used by the intelligent buildings of the city. In order to do that, the surplus of energy is signaled by the energy suppliers towards the owners of intelligent buildings in the city by means of usual communication technologies. In our case, a smartphone app is used. The house owners can then react by turning on additional power loads such as domestic appliances (e.g., white goods, air conditioning units or heat pumps), as well as electric cars and vehicles. By that, the energy supply within the city could be balanced in a better way by the swarm behavior of the intelligent consumers by activating additional power loads.

B. *Use case (UC2): Insufficient or lack of renewable energy*

Let us assume for use case (UC2) that the power consumption and load in the city reaches its maximum level. During the same time frame, the feed-in of renewable energy is diminishing at minimum because of wind calm or the lack of sun radiation (e.g., at night). This lack of electric power shall be balanced, at least partly, by the intelligent buildings of the city. In order to do that, the lack of energy is signaled by the power providers towards the owners of intelligent buildings in the city by means of usual communication technologies. The house owners can then react by switching off domestic appliances (e.g., white goods), set air conditioning units, or heat pumps into eco-mode and deactivate charging stations for electric cars and vehicles. Therefore, the energy supply within the city could be balanced in a better way by the swarm behavior of the intelligent consumers by de-activating power loads.

IV. CONCEPT AND OVERALL SYSTEM DESIGN

The core concept is to balance loads in power grids by using KNX-enabled Smart Homes and a communication infrastructure based on NGN technologies and the Presence Service. The essential idea of this approach is to publish data of actual power consumption and power reserves of selected Smart Home appliances by use of the NGN Presence Service to the outside world. In a second step, the corresponding energy supplier could subscribe to this data of actual energy consumption and reserves. Based on this data, the energy supplier is enabled to send specialized offers towards the Smart Home owners in order to manage a surplus or lack of renewable energy, enabling a feedback control and power regulation within the smart grid.

NGN technologies are used to build an integration platform between mobile devices and intelligent buildings with a home automation solution. As depicted in Fig. 1, a Signaling Gateway interconnects the NGN core network and the Smart Home.

To interconnect the two architectures, a special gateway is needed. The gateway manages connections between the SIP-based NGN and the single appliances of the Smart Home solution. In this system, the NGN infrastructure consists of an IMS [11].

The IMS is a control architecture based on the standardized SIP [12] designed by the wireless standards body 3rd Generation Partnership Project (3GPP). It aims to standardize access to different networks. Therefore, all communication is based on the Internet Protocol (IP).

An important functionality of the IMS is the Presence Service, which enables to represent different home automation appliances as users to the outside world. Each appliance can set its own current status. Thus it is possible to register a mobile device at the SIP network, and in this way at the Presence Server. Hence, the status information of the different home automation appliances can be viewed on a mobile device.

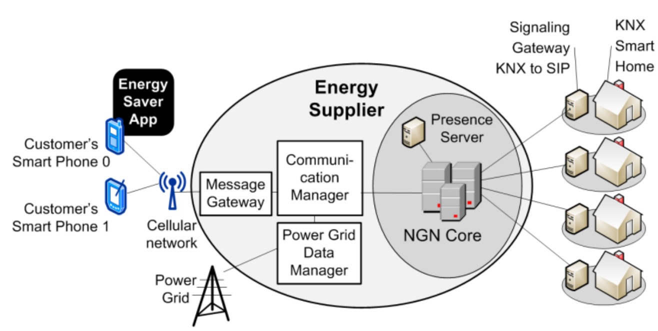

Figure 1. System overview.

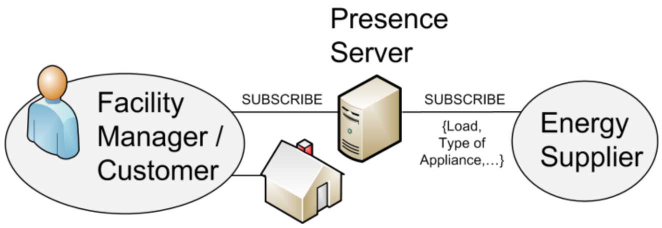

Figure 2. Basic system functionality and interaction between customer, energy supplier and Presence Server.

The Signaling Gateway is responsible for updating the status information at the Presence Server. For example, any time a sensor in the home automation system changes its status, an update has to be sent by the gateway.

At the energy supplier, the software component Communication Manager is the core component that contains all business logic to assess load data from the power grid, organized by the Power Grid Data Manager, and data collected from the Presence Service. A Message Gateway is used to send messages to the Smart Home owner's smartphone.

V. Components

In the following section, we describe the components that are used to build our system. The description is divided into three subsections, each presenting different levels of interaction within the whole system.

Basically, this approach extends the core technology mentioned in our previously published work by implementing a push service [2, 3, 4, 5]. Additional components have been integrated to accomplish the task defined in this paper. Subsections A and B describe these new components. Subsection C provides an overview of the core system that has been continually refined.

A. *Interaction between Energy Supplier and Smart Home*

The corresponding Energy Supplier system registers itself at the Presence Server (see Fig. 2). In a second step, the energy supplier subscribes to the data sets of actual energy consumption and reserves. Status data from all Smart Homes connected to the Presence Server is continuously monitored by the Communication Manager component (see Fig. 1). Status data from the power grid is collected through the Power Grid Data Manager component. Comparing these two data sources, the system is able to detect situations in the power grid as described in use cases UC1 or UC2 (see Section III). Then, offers are calculated that match the specific capabilities of the relevant Smart Homes in a given area and sent out via the Message Gateway component.

B. *Interaction between Energy Supplier and Smart Home Manager*

At the Energy Supplier, a core component encapsulates the system's business logic (Communication Manager, see Fig. 1). Communication to the Smart Home Customer's smartphone is set up and controlled by the Message Gateway component. At the mobile device, the EnergySaver App is implemented as an extension of our Android SIP client described in Subsection C. A web service is implemented at the Message Gateway that interacts with the smartphone communication component by means of push notification [21].

The EnergySaver App receives and displays messages from the Energy Supplier containing offers to the Smart Home customer as described above. The customer then is able to accept or decline a specific offer. If the offer is accepted, the customer's Smart Home appliances are set up accordingly, communication being done through the infrastructure described in Subsection C. For example, power reserves of specific appliances can be released into the public network after accepting a suitable offer.

C. *Interaction between House Manager and Smart Home*

In this subsection, the core system that provides interaction between the House Manager and the Smart Home is described.

1) *Next Generation Network Core*

To set up the NGN Core networks, we evaluated two solutions to guarantee that the signaling gateway is able to work with different NGN platforms.

As a lightweight solution to realize the NGN Core, a SIP server with a Registrar and a Presence Service is used. This common SIP server also provides all the functionality that is needed to set up a SIP-based communication and integration platform. SIP is a signaling protocol for controlling multimedia communication. It can be used to create, modify or terminate a multimedia session, which can exist between two parties or multiple parties.

The Session Description Protocol (SDP) [13] describes properties of multimedia sessions. SDP is used by SIP for negotiation regarding media codecs, transport protocols and transport addresses. SIP for Instant Messaging and Presence Leveraging Extensions (SIMPLE) [14] describes a presence and instant messaging protocol suite based on SIP.

Instant messaging enables users to communicate by text. For the Presence Service, a User Agent (UA) has to register at a Presence Server. The server acts as a Presence Agent. It stores the status of the UA. Other users (subscribers) can subscribe to the UA's presence information. Every time the UA changes its status, the subscribers will be notified by the Presence Agent.

2) *Mobile Device*

We chose Android 2.2 [15] as the development platform for the mobile device prototype. After we evaluated different SIP APIs for Android, we chose CSipSimple [16], because only CSipSimple is able to send SIP messages conforming to the RFC3428 standard. CSipSimple is an open source VoIP application for Android using SIP. Based on CSipSimple, we built our own Android SIP client prototype including our own GUI and the functionality to display and change presence states.

3) *KNX*

The KNX system [17] is the only worldwide standard for home automation and intelligent building control.

 ISBN: 978-1-61208-282-0

KNX was invented in response to the following shortcomings: In conventional home installations, the control line and the power line are not independent from each other. For example, lights are controlled by turning their power on or off. Complex control mechanisms are hard to implement, and to change a wire-bound energy-controlled system after its installation is very complex. Therefore, power and control lines in the KNX standard are independent from each other.

The KNX standard supports the following communication media: Twisted pair (TP) wiring, power line (PL) networking, radio frequency (RF) and Internet Protocol over Ethernet (KNX/IP or KNXnet/IP).

4) Signaling Gateway

The signaling gateway, depicted in Fig. 3, is the central component of this concept. This software service connects the KNX bus to the NGN components.

Every sensor and actor that is connected to the KNX bus gets its own address (SIP URI) to log on to the service. Registering each KNX device in the Presence Service, allows storing the current status of the device, like “on” or “off”. Each device update received from KNX is converted to a SIP request and sent to the Presence Server. Now the user of the mobile device can monitor and even change the current status for each KNX device. Every change is then transmitted back to the KNX bus.

With a KNXnet/IP (interface between KNX and Ethernet) device, KNX telegrams can be transferred to the IP network. The whole telegram is transmitted over the network as payload of an IP packet. Thus, one functionality of the signaling gateway is to receive these IP packets sent by the KNXnet/IP device. Furthermore, the information in the telegram has to be extracted. This could consist of sensor values or other status messages of different home automation appliances.

The KNXnet/IP device is also able to receive IP packets sent via the IMS from the IP network and forward the containing telegram to the KNX bus. Thus, in order to control appliances that are associated with the bus installation, the signaling gateway has to have the ability to generate KNX telegrams.

The framework Calimero 2.0 is a collection of Java APIs that form a high level framework for communication with a KNX installation with the use of KNXnet/IP [18].

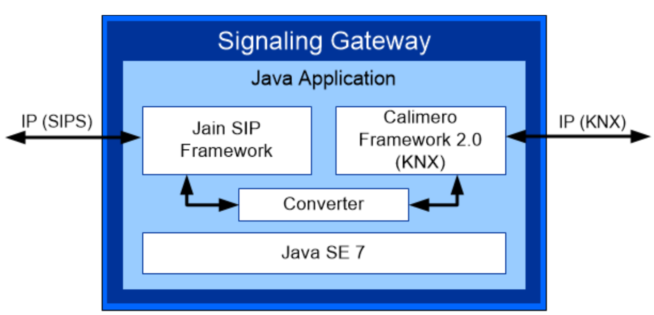

Figure 3. Connection interfaces of the Signaling Gateway

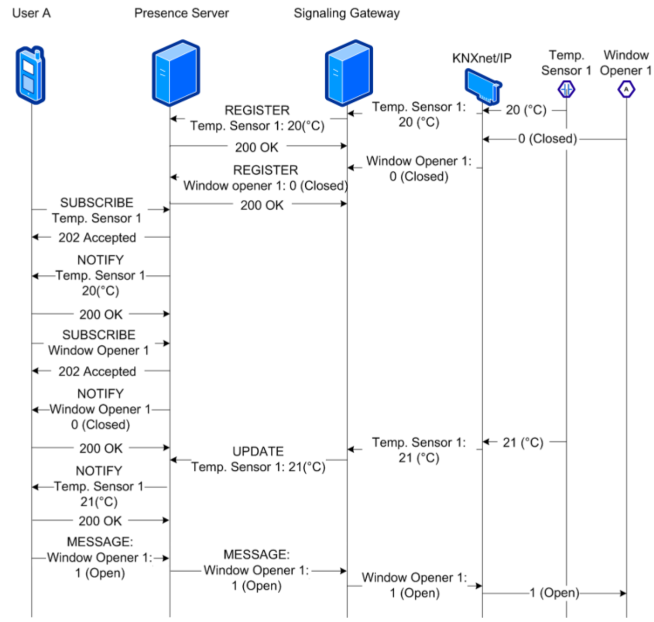

Figure 4. Complete message flow, ranging from registration of the KNX devices to the control of the KNX devices.

The framework aids in building high level applications that need to communicate with the KNX bus system for remote access and control. It can receive and decode KNX messages as well as send and encode its own KNX messages. This framework is used in the signaling gateway to handle communication with the KNX bus.

Once the information of the telegram has been filtered, the status change must be transmitted to the Presence Server located in the IMS. This leads to the second main functionality of the signaling gateway: The connection to the IMS. To accomplish this, the Jain-SIP (JSIP) framework [19] for Java is being used. The signaling gateway registers every appliance of the KNX bus installation as a "user" at the Presence Server. To set the status of a user, a SIP message must be sent through the IMS network. This message flow is depicted in Fig. 3. To view the current status of a part of the home automation system, the mobile device only has to subscribe to the Presence Server.

If a user wants to control an appliance of the home automation system, a SIP message is sent from the mobile device to the signaling gateway. Furthermore, the information in the SIP message body must be converted to a KNX telegram. This body is optional and can include messages written in SDP, SOAP, XML or ASCII.

Furthermore, status data of energy-related appliances in the Smart Home are published to the Presence service. This includes type of appliance (see use case description in Section III), power source/power sink, load characteristics and capacity as well as other parameters. Not every appliance in the Smart Home is reflected in this data set, but only the most important ones with the largest impact on load balancing, e.g., powerful car batteries or freezers.

This data is pseudonymized by means of a hash function, meaning that regular customer identifiers are replaced by other identifiers that only allow the energy supplier to

 ISBN: 978-1-61208-282-0

reconstruct the customer's identity. Therefore, no personal data is transmitted via the Presence Service. Because of this, the proposed system is in accordance to national legal regulations, for example the German “Bundesdatenschutzgesetz” (Federal Data Protection Act) [20].

VI. System Security

Without an implementation of suitable security measures, the system could be compromised by attackers. Therefore, it is necessary to ensure a secure connection to the mobile device and a secure authentication for the user. In this section, a security approach is introduced that will be used to secure the end-to-end network communication of the system as shown in Fig. 1. At the current development stage of the system, only a basic security model is assumed that primarily considers attackers from outside.

A. SIPS Introduction

SIP Security (SIPS) is using Transport Layer Security (TLS) and the Secure Real-Time Transport Protocol (SRTP). SRTP are used for secure Voice- and Video-Data connections, TLS is used for exchanging signaling messages (e.g., authentication and registration).

TLS is a hybrid encryption protocol for secure data connections over the internet. In the OSI reference model (Fig. 4), TLS is acting at the transport layer. In SIPS, TLS takes care of the following security tasks:

- Bidirectional authentication of communication endpoints
- Exchanging a shared secret
- Cryptographic encoding of data to be transferred
- Securing integrity of transferred SIP messages

To prevent possible man in the middle attacks, TLS can be extended with digital certificate authentication [22].

B. Evaluation of system security

We measure the security of the selected approach according to the four pillars of information security [23]:

- Confidentiality
- Integrity
- Availability
- Authenticity

As described above, SIPS is using the protocols TLS and SRTP for secure communication. TLS uses a high security encoding and grants therefore high confidentiality. The TCP/IP protocol ensures integrity by adding a checksum to each message. Authenticity is granted by authentication with credentials. The SIPS availability is given as long as the SIP server is connected to the internet.

Furthermore, software aspects like performance, scalability, manageability and cost have been evaluated.

Compared to an unsecured and connectionless UDP connection, a TLS connection is less performant. The reason for this is that SIPS is based on connection oriented TCP, which needs significantly more resources. Encryption is also costly. This fact also reduces the scalability of such a system. Because of the wide-spread use of SIPS, there are many frameworks and libraries, which make SIPS easily manageable and implementable.

If a certificate is used to ensure the identity of the communication partners, a disadvantage of TLS are the costs to buy trusted certificates from a Certificate Authority [24].

Other security models have also been considered for the system. A Virtual Private Network (VPN) is a possible approach, but would not be feasible [25]. The VPN needs to be set up before using the mobile client and to be closed after using the mobile client. Closing it in between will disconnect the mobile client from the SIP server. An active VPN connection uses additional internet bandwidth and battery power, because it needs to stay active as long as the application is running.

We also don’t recommend the use of an ID Token [26], because of the implementation effort, the low performance and the extra cost for an ID Token reader/writer.

We choose SIPS for this system, as it is easy to implement (because TLS is supported by all software used for the prototype) and ensures a high level of security. Still, loss of the mobile device is a security risk to be prevented. This could be done in combination with a password for authentication with the system, or even an ID Token could be used (as a password). Now, after the loss of the device, only the password needs to be changed or disabled, to prevent unauthorized access.

VII. Actual Status of the Prototype

The prototype consists of a fully addressed and configured KNX TP bus system with different kinds of sensors and actors like weather station, dimmers and digital/analog switches for lighting and power outlets. The signaling gateway is implemented as a Java application using the Calimero 2.0 framework and the JSIP framework. The Calimero framework is used for communication with the KNX bus via the KNXnet/IP interface. Every KNX device gets translated as a SIP UA and therefore can be accessed individually.

The Presence server is implemented as a servlet using the Sailfin framework for SIP on a GlassFish-Server. Sailfin offers a full featured Presence service and SIP call control functions.

The mobile client is implemented as an Android application based on a modification of the open source software called CSipSimple for Android. The mobile client can get a list of all UAs for the KNX devices by sending a message to a specialized UA in the signaling gateway, which sends back the SIP URIs for the devices. With this list, the mobile client can subscribe to each device at the Presence server. Direct messages to the KNX devices can change the status of the device. The devices themselves can publish their status to each subscribed user.

The communication between each party is secured by using the TLS protocol. The Sailfin, JSIP and the CSipSimple framework all support TLS and authentication, no own implementation of TLS is needed.

The EnergySaver App has been implemented as a prototype.

 ISBN: 978-1-61208-282-0

VIII. CONCLUSION AND FUTURE WORK

The presented solution enables a secure and trustful interaction between intelligent home control managers and the energy suppliers of the smart power grid.

The interaction between house manager and smart home is implemented as mobile, ubiquitous, two-way home control solution based on SIP and the Presence Service. Hereby, the house manager could control all smart home appliances (e.g., actors and sensors) in real-time via his Android-based smartphone. It is realized as secure TLS connection based on SIP Security from the smartphone towards the signaling gateway, which is typically located inside the smart home.

The interaction between energy supplier and smart home is mainly effected by the Presence Service, which publishes the data of actual power consumption and power reserves of selected smart home appliances to the outside world. The Presence Service is a well performing, scalable, field-proven, near-real-time push-solution of the energy data sets towards the corresponding energy supplier. The described solution is trustful, because data privacy protection could be fulfilled easily by pseudonymization or anonymization of the energy data sets on the presence server side. By that, our solution respects the right to data privacy protection of the smart home owners.

The interaction between energy supplier and smart home manager is characterized by a half-automated energy load management solution. Our solution respects the rights of property and self-determination (autonomy) of the smart home owners, because they have to agree to the energy management offer made by the energy supplier.

It has to be noted that this kind of interaction is limited to day-time use only. Appropriate automatisms should be applied for the time users are sleeping or are "off-line". This will be addressed in future work. Furthermore, another point is to make the mobile client platform independent and to introduce a security model that exceeds the basic considerations described herein.

ACKNOWLEDGMENT

This work has been performed within the project "Smart Home Control" at Hochschule Darmstadt (University of Applied Sciences). The authors would like to acknowledge the support of Albrecht JUNG GmbH & Co. KG for their contribution of KNX actors, sensors and other KNX home automation devices and kind support.

REFERENCES

[1] Infonetics Research, "IMS equipment and subscribers report", 10/17/2012.

[2] R. Acker, S. Brandt, N. Buchmann, T. Fugmann, and M. Massoth, "Ubiquitous Home Control based on SIP and Presence Service". In: Proceedings of the 12th International Conference on Information Integration and Web Based Applications & Services (iiWAS 2010), ACM, 2010, pp. 757–760.

[3] M. Massoth et al., "Ubiquitous Smart Grid Control Solution based on a Next Generation Network as Integration Platform". In: Proceedings of the 1st International Conference on Smart Grids, Green Communications and IT Energy-aware Technologies (ENERGY 2011), IARIA, 2011.

[4] R. Acker and M. Massoth, "Secure Ubiquitous House and Facility Control Solution". In: Proceedings of the 5th International Conference on Internet and Web Applications and Services (ICIW 2010), IEEE Computer Society, 2010, pp. 262–267.

[5] M. Massoth et al., "Security Assessment of an Ubiquitous KNX based Home Control Solution using SIP and the Presence Service". KNX Scientific Conference 2012, University of Las Palmas de Gran Canaria, 2012.

[6] KNX Association, http://www.knx.org/knx-standard/standardisation, [retrieved: April, 2012].

[7] HomeSIP Project, http://www.enseirb.fr/cosynux/HomeSIP/, [retrieved: May, 2013].

[8] B. Bertran, C. Consel, P. Kadionik, and B. Lamer, "A sip-based Home Automation platform: an experimental study", Proc. 13th International Conference on Intelligence in Next Generation Networks, 2009 (ICIN 2009), IEEE Press, Oct. 2009, pp. 1-6, doi: 10.1109/ICIN.2009.5357075.

[9] C. Bertran, C. Consel, W. Jouve, H. Guan, and P. Kadionik, "SIP as a universal communication bus: a methodology and an experimental study", Proc. 2010 IEEE International Conference on In Communications (ICC 10), IEEE Press, July 2010, pp. 1-5, doi: 10.1109/ICC.2010.5502591.

[10] D. Lechner, W. Granzer, and W. Kastner, „Security for KNXnet/IP". In: Proc. KNX Scientific Conference Nov. 2008.

[11] J. Soininen (Ed.), "Transition scenarios for 3gpp networks", IETF, RFC 3574, Aug. 2003.

[12] H. Schulzrinne et al., "SIP: session initiation protocol", IETF, RFC 3261, Jun. 2002.

[13] M. Handley, V. Jacobson, and C. Perkins: "SDP: session description protocol", IETF, RFC 4566, Jul. 2006.

[14] SIP for Instant Messaging and Presence Leveraging Extensions (SIMPLE). IETF Working Group

[15] Android, http://www.android.com, [retrieved: May, 2013].

[16] CSipSimple, http://code.google.com/p/csipsimple, [retrieved: May, 2013].

[17] KNX Association, "KNX logical topology faq", 2005, [retrieved: May, 2013].

[18] Calimero 2.0, http://calimero.sourceforge.net/, [retrieved: May, 2013].

[19] Jain SIP Framework, http://jsip.java.net/, [retrieved: May, 2013].

[20] Bundesministerium der Justiz, „Bundesdatenschutzgesetz in der Fassung vom 14. Januar 2003, zuletzt geändert am 14. August 2009", Berlin, 2009.

[21] W3C, "Web Services Description Requirements. W3C Working Draft 28 October 2002". http://www.w3.org/TR/ws-desc-reqs/, [retrieved: May, 2013].

[22] BSI, „VoIPSEC Studie zur Sicherheit von Voice over Internet Protocol", https://www.bsi.bund.de/ContentBSI/Publikationen/Studien/VoIP/index_htm.html, [retrieved: May, 2013].

[23] A. Menezes, P. van Oorschot, and S. Vanstone: "Handbook of Applied Cryptography (Discrete Mathematics and Its Applications)", CRC Press, 1996.

[24] Microsoft, "Digital Certificates". http://support.microsoft.com/kb/195724, [retrieved: May, 2013].

[25] M. Lewis, "Comparing, Designing, and Deploying VPNs", Chapter 1, Cisco Press, 22.04.2006.

[26] RFC 2808: The SecurID(r) SASL Mechanism. http://www.ietf.org/rfc/rfc2808.txt, [retrieved: May, 2013].

Methodology for Studying the User Experience with New Mobility Systems: The Cases of Electric Cars and Dynamic Car-pooling Use

Béatrice Cahour
National Centre of Scientic Research
and Télécom ParisTech Sup.School
Paris, France
beatrice.cahour@telecom-paristech.fr

Claudine Nguyen
Renault and
Télécom ParisTech Sup.School
Guyancourt, France
claudine.nguyen@renault.com

Lisa Créno
VeDeCoM Institute and
Télécom ParisTech Sup.School
Paris, France
lisa.creno@telecom-paristech.fr

***Abstract* – The use of emerging mobility systems in the city is a critical issue, and we propose in this paper a methodological framework, which is lived experience-centered, to study it. The methodology is illustrated with two studies: the first is about the way drivers deal with the limited autonomy of electric cars, and the second is about the use of dynamic car-pooling. We propose three steps: (1) studying a situation of reference, with interviews focused on the lived experience of specific situations of use, (2) studying the lived experience of a limited population in the emerging situation, with video recording and interviews based on the video and on diaries (3) generalizing some of the processes observed with quantitative data. We then discuss the pros and cons of this methodological approach, and we explain the resources it provides for designing technologies and services adapted to the users' activities and feelings in natural settings.**

Key words : methodology; natural use; lived experience; electric cars; dynamic car-pooling; interviews; reference situation

I. INTRODUCTION: STUDIYING THE EMERGING USES

Mobility in the future cities is a crucial social issue because of the ecological, economical and traffic congestion impacts of the design of multi-modality systems. New modalities of mobility must be experimented to be adapted to the users' expectations, reluctances, and practical organization of their daily life.

We can find mostly global and statistical approaches looking at the flow of travels, at the profiles of the persons using new modalities of transport and macro description of the users' behaviour and motivations [1]; [2]; [3]; [4]; [5]; [6].

The approach that we present here is focused on analyzing how people deal effectively with the use of new mobility systems in their daily life (and not only on what they say about what they generally do or will do). It is focused on the situated activity [7] and on the lived experience of the users in specific contexts [8], [9]. We adopt a psycho-ergonomic perspective:

- A psychological perspective : exploring precisely the user experience with the new technology and service : their actions but also what they think during the use and how they feel [10];
- And an ergonomic perspective: proposing orientations for designing tools and services adapted to the user's situated activity.

The difficulty is that these new services and technologies are not developed yet in the city and we cannot really experiment them in the real context of the future city. It is then a matter of "prospective ergonomics" [11], of anticipating the future situation and the activities deployed in this context. We could base our study on the projective imagination of the future users, like it is often done in creativity sessions. But there is a potential gap between the intentions and the actions actually developed. We then prefer to study how people behave in a real situation. If this situation does not exist so far, maybe we can find an existing one, which is a reference (also for the users), and then develop a situation, which is similar to the future one, but on a smaller scale.

Our conception of User Experience is based on an in-depth analysis of the situated activity and lived experience, i.e., on what happens during the contextual use and how the user lives it: what are their actions and focus of attention; their mental activities for evaluating, reasoning, taking decisions; their sensorial perceptions and their affective feelings [8].

As examples of this methodological process, we will present two studies:

- The first study is about the initial use of an electric car and the specific issue of its limited autonomy [12], [13]; how do users deal with this new situation where the risk of breaking down is more important? (about 150 km of autonomy). Are they taking some risk with unpredictable routes or are they limiting their travels? How do they feel with the risk of running out of car energy, and how do they manage it when driving or before driving?
- The second study, which began recently, is about the use of dynamic car-pooling with service applications on smartphones. How do the users find another user

 ISBN: 978-1-61208-282-0

to share a personal car during a travel? Is the application satisfying? What is the relevant information about the other? Are they trusting the others or not, especially when they are strangers: their way of driving, their punctuality, their social behaviour? What type of social relation do they build during the travel?

We proceed in three steps:

- Studying a situation of reference;
- Studying the lived experience of a limited population in the emerging situation (with the new service or technology);
- Generalising some of the processes observed with quantitative data.

II. EXPERIENCE-CENTERED METHODOLOGY AND RESULTS

Our methodological framework is inscribed in the disciplines of psychology and ergonomics. It allows us to study the human lived experience and activity with its cognitive, emotional and sensorial aspects, with the ergonomic objective to design instruments and environments, which are adapted to the human needs.

A. Step 1: studying a situation of reference

In a first phase we study an existing situation of reference. This situation must be the most similar to the future situation that we aim at.

1) Situation of reference for the EV autonomy management

For studying the issue of how people act and feel regarding the limited range of the electric vehicle (EV), we first studied how people act and feel regarding the autonomy of *their traditional thermal vehicle*; we had no idea about this specific activity, which is adjacent to the driving activity but becomes very important with the EV.

14 in-depth interviews (half men/women, 23 to 63 years old) have been performed. After a general description of how they tend to manage the autonomy, we asked them to try to remember and describe the lived experiences of specific situations.

We then analyzed the interviews, and from this analysis we constructed a short questionnaire of 7 items to get quantitative data on specific points, which appeared to be relevant, filled by 344 drivers (21 to 65 years old).

We will not develop here all the results but only the main ones.

First of all, concerning the way people deal with the autonomy of their traditional thermal vehicle, the interviews and questionnaires allowed us to highlight different *styles* [12]: some drivers are more or less worried about running out of gasoline and consequently they anticipate and calculate more their refilling. The styles (anticipators, moderate anticipators, reactive to the signal, late refillers), which are a global tendency to act in a certain way, depend on personal determinant, but this global tendency can also be transformed by contextual determinants:

- Personal determinants are: (1) the affective relation to the risk of breaking down, some being anxious of breaking down and others being rather indifferent to this possibility; (2) the affective relation to the stations, some delaying the refilling because they feel the stations as disgusting and unpleasant places that they avoid.
- Contextual determinants are (1) the temporal priorities of the driver at that moment (refilling may be considered as less important as being on time at a meeting); (2) the trust in the reflexive instruments of their own cars indicate the remaining autonomy (such as the gauge); (3) the familiarity with the journey and station sites (for long and unknown trips, there is more anticipation); (4) the collective influence (when sharing a car with someone else, the refilling can be more systematic).

The more surprising results are the variety of reactions towards the uncertainty of the autonomy, and the diversity in terms of tolerance to uncertainty [14]. Also the emotional relation to the risk of running out of gasoline appears to be clearly linked to the proactive/reactive conduct, but models of risks surprisingly ignore this emotional dimension [15].

We also observed that, for dealing with the autonomy, drivers use instruments [13] of two types : (a) to anticipate and calculate in advance the risk, such as websites, and it is mainly done by those of the "anticipator" or "moderate anticipator" style (b) they also use reflexive instruments, which give them a dynamic feedback on their situation state (the gauge, the remaining kilometers, the econometer); some "late refillers", who are used to breakdown, can even have a can in the trunk and a pipe in order to cope with (and not anymore to avoid) the breakdown.

2) Situation of reference for the dynamic car-pooling

Car-pooling is defined as the sharing of a private vehicle between persons who may or may not know each other in advance, and who can meet by using a service on the web allowing them to find other persons to share a ride. Nowadays in France, this mapping is always performed in advance (we call it "planned" car-pooling); the planned car-pooling is mostly used for long trips (in Europe, the average is 200 km, [16]. The "dynamic" car-pooling implies that a system geolocates the potential users, identifying dynamically where they are. The matching between users is based on this geolocation. Consequently a person can go out of a meeting at anytime for instance, look on his smartphone at who is in the neighborhood and going in the same direction as himself. The mapping is then dynamic and users do not need any more to plan their ride in advance. Dynamic car-pooling services are not already functional in France, but some applications are used elsewhere, such as Avego Driver in Ireland.

We first studied the present services of car-pooling to have a clearer idea of why people do not use this type of service and if they do, how do they do. Some studies have already been conducted on this issue but with a more global perspective [17]; [18]; [5]; [19]; [20]. They indicate that, in France, car-pooling is occasionally used for holidays or for a special event, mainly by young users (60% are under 30 years) living in urban environment. The drivers are a majority of men (69%) and 34% of them are more than 40 years old; the passengers are rather women and 26% of them are less than 23 years old. Users say that the positive points are economic (low price of their travel), ecologic (reduction of greenhouse gas emissions) and social (meeting new people and creation of a social link). The negative points are the lack of flexibility in scheduling and journey [21], but dynamic car-pooling should respond to this problem.

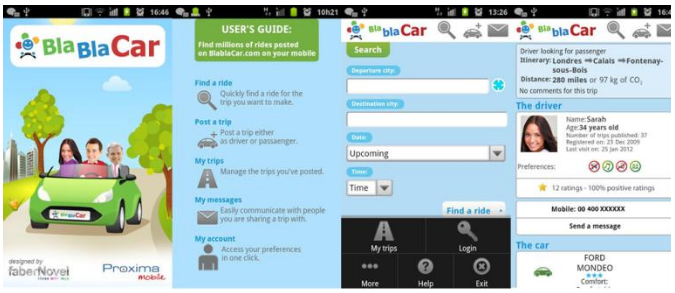

Figure 1 : Searching a travel and a driver/passenger on BlaBlaCar! (application of "planned" car-pooling available on App Store and Google play : [22])

Firstly, 25 interviews have been conducted with people who never used any car-pooling systems to know their motivations for not using it.

Then *25 in-depth interviews* have been conducted (with descriptions of real uses cases) with people using planned car-pooling. The objective was to specify the sources of reticence and appreciation but also the difficult or positive experiences they have had with this mode of mobility. The issue of trust/mistrust is particularly important: how do users construct a trust or mistrust in this service? Do they choose the persons with whom they share a car and how? What type of interactions do they have once in the car? What is the nature of the social interactions built in these circumstances? Do they feel a risk or not and which type of risk? This study is then questioning and completing the theories of risk-taking and trust [23]; [24]; [15]; [25]. The analyses of these data are in progress.

3) Interviews focused on the lived experience of specific situations

The in-depth interviews that we conduct for studying the situation of reference are based on a specific technique, called "explicitation" (or "elicitation") interviews, which has been developed by Vermersch [26]; [9]; [27]; [28]. First of all, the interview is focused on the description of real use cases, of effectively lived experiences.

The typical risks when getting verbalizations from subjects describing their activity are the rationalizations and re-construction. The more we take care of the recall process of the subjects, the more we limit this risk. The "explicitation/elicitation" interview aims at the phenomenological experience of the subject [29], and is very cautious on the recall process. One principle is to help the subject to get a vivid memory of the activity by asking questions about the sensorial context. Then, we ask questions always linked to the situation to avoid generalizations, and taking care of their non-indicative format for not influencing the response of the subject. These techniques keep the subject in a position of talk which is focused on what he was living cognitively, perceptively and affectively during the past experience. It does not orient the subject to provide rational comments and explanations about it. The interviewer follows the temporal course of experience described by the subject and helps him to give more information about what happened in a specific situational context. With this interview technique, the subject has a vivid recall of the situation he describes (if not, he is invited to tell it) and can give more details about it and limit the rationalizations.

4) Transfer from the reference situation to the future situation

The situation of reference is a first basis to think about the emerging situation and to have indications and intuitions about how this future situation will probably be lived and acted by the users.

For instance, we observed different styles for dealing with the autonomy of the vehicle: some drivers being more worried and anticipating more than others who wait for the signal of energy stock or even far after it. These styles are tendencies to act in a certain way, more or less anticipative or reactive, more or less worried about a certain risk or indifferent to this risk. They could not totally change because the vehicle becomes electric, except if the infrastructure totally transforms the activity and the nature of the risk (if there is for instance plenty of electric charging points everywhere, or if we could exchange the battery everywhere). But it is not the case yet, and even then, the user will need to wait for the service (the charge will take some time) and will plan it (or not) in the course of his/her activity. Then these profiles will remain relevant for anticipating the lived experience in the future.

For the case of the 'planned' car-pooling, we intend to extract a lot of relevant information for the emerging 'dynamic' car-pooling; the situation is very similar except that the activity becomes more opportunistic and reactive than with the planned car-pooling, and may unable the users to get as much information about the car-pooler to build trust through his profile and the opinions posted.

B. Step 2: studying the lived experience of a limited population in the new situation

The second step is, according to us, the most important one; it is the core of the user experience research, the phase of analysis of the users' actions, perceptions, cognitive activities and feelings when using the new technology or mobility service.

1) Studying the lived experience with electric vehicles

For studying how people dealt with the limited autonomy of electric vehicles, electric cars have been lend to 9 subjects (7 men, 2 women, 24 to 55 years old, of the four styles). The lend cars are of three different types and trends, their official electric range is from 150 km to 160 km and the time needed to fully charge the battery is 7-8 hours. They used them during two weeks as they wished, without any constraint. The activity and user experience were studied by:

- Observing via *video recording* (3 cameras) the emerging use with the new technology in ecological settings (cf. fig.1);
- Asking the 9 users to fill a *diary* every day about (1) The journeys: destination, planification, unexpected events, renunciations and motivations; (2) The recharge: mode, place, impressions and others remarks (3) Others impressions or specific events with the EV;
- Interviewing the users, with explicitation *interviews* (after days 1, 8 and 14) based also on the *video* recordings and on the *diaries* (self-confrontation interviews) in order to know the subjective experience when using the new mode of mobility.

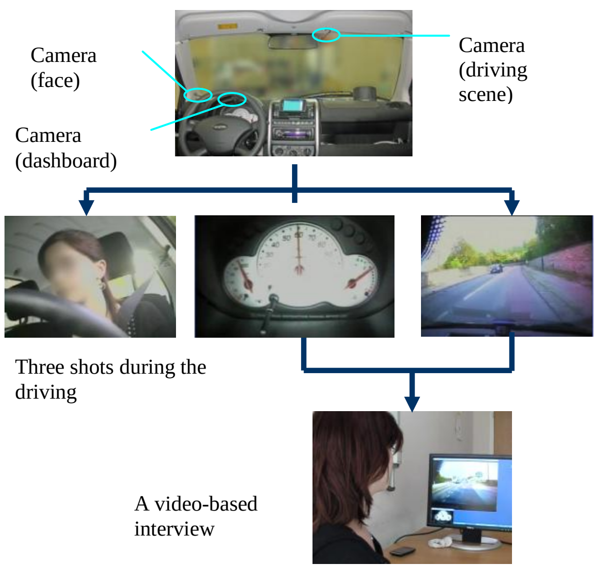

Figure 2 .Illustration of the use of the video recordings

The main results are:

Most of the subjects limit the risky journeys and use the electric vehicle (EV) for well-known journeys such as from home to work. Only two subjects with the profile “late refillers” have taken the risk of driving the EV with very limited autonomy. This indicates that the styles of reactions with traditional cars are similar with EV and that we find again this differentiated styles of dealing with the autonomy issue.

The study indicates how the EV driving experience is situated and anchored in the context, and how it is emotionally embodied [12]. We showed how the activity and feelings of the driver depend on:

- The *reflexive instruments* available and their interpretation (gauge, econometer, other signals) ; the construction of their meaning depends on the style of anticipation and worry;
- The *geographic context* (hills, proximity of the arrival); the driver constructs a representation of it to anticipate the evolution of his autonomy, since some electric energy can be gained when going down hills and using the motor brake;
- It also depends on the co-drivers’ reactions. When the car is shared by a couple for instance, the actions taking place are negotiated.

The use of the different “reflexive” instruments (gauge, econometer, remaining kilometers) have been studied in details, including the evolution of the use during the two weeks. For instance the econometer is often ignored at the beginning but finally used when critical situations arise.

Finally, we proposed two prototypes of instruments (developed by Renault) to the 9 subjects who had used the EV during two weeks. The prototypes proposed innovative applications for geolocating the places for charging, the distance and time to these places (from the present place of the driver), but also visualizations of their remaining charge and other information, which is relevant for the autonomy. We asked them about what would fit them and which other expectations they would have, projecting them in the future possibilities.

2) Studying the lived experience of the dynamic car-pooling

For studying how people act and feel with the dynamic car-pooling, we will soon disseminate an application with geolocation, which is not used in France but is developed in Ireland (Avego Driver) and a very new application, which is developed by a French start-up. We disseminate it in a zone of the south suburb of Paris, in several companies and engineer schools.

When a sufficient number of persons will use the service, we will ask some volunteers to videotape (using small wearable cameras like “glasses-camera”) some moments of their natural activity, like the search of an adequate partner for the car-pooling, the arrangement of the meeting and the encounter. We will also put a video camera in the cars of some car-poolers to analyze the social interactions taking place with strangers.

Users will also fill in diaries and some volunteers will be interviewed with the techniques described above (explicitation interviews and interviews based on the video records and on the diaries).

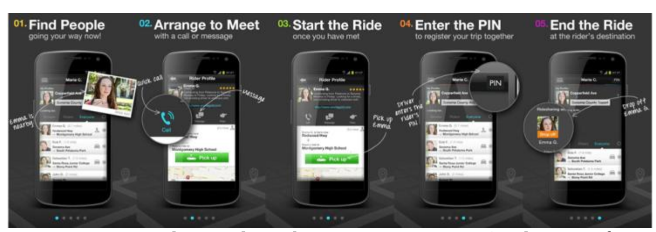

Figure 3: Searching and matching on Avego Driver (application of dynamic car-pooling available on App Store and Google play : [30])

C. Step 3: generalising some of the processes observed with quantitative data

Our approach of the user’s activity and experience is globally qualitative. Nevertheless it is interesting to quantify on a larger scale of population some of the processes put into light during the first two steps.

That was the case for the EV autonomy study. With a short questionnaire and 344 participants we could for instance specify the quantitative repartition of the styles

 ISBN: 978-1-61208-282-0

found in the qualitative interviews, and looked more precisely at the link between the anticipation tendency and the worry concerning the limited range of the vehicle.

The "*anticipators*" represented 17,4% of our population. To the question of the questionnaire "In general, in your daily life, you go and take some gasoline...", they responds "far before the signal of energy stock". 48,3% of them are "rather worried" or "very worried" "when the stock signal comes on". They are pro-active to avoid the stress of the failure risk.

The "*moderate anticipators*" represented 36,6% of the population; they tend to re-supply the vehicle "just before the stock signal". The autonomy management is more serene since 22,2% of them are "rather worried" or "very worried" when the stock signal lights on.

The drivers who are "*reactive to the signal*" represented 29,9% of the population; they generally wait "right after the stock signal (1 to 15 km)" for re-supplying. Only 6,9 % declare to be "rather worried" or "very worried" when it lights on.

The "*late refillers*" (16,3%) who get some energy "far after the signal (more than 15 km)" are also only 7,1% feeling "rather worried" or "very worried" when the signal lights on. They run out of gasoline sometimes.

It was actually interesting to know how these profiles are distributed in a larger population and to confirm the co-variation between the anticipative-reactive behavior and the affective relation to the risk of running out of energy.

The quantitative analysis is following the qualitative studies and completes the information on some specific processes. The in-depth qualitative analysis of the processes is a resource to build a relevant questionnaire.

III. Discussion

Innovative modes of mobility such as the use of electric cars and car-pooling can be very efficient ways to build ecologic cities with less traffic and a better quality of life. Sharing cars is also a way of improving the economy of the households and of developing social conviviality. It is necessary to know how users deal with these new services and technologies, and our psycho-ergonomic approach is complementary to more macroscopic economical or sociological studies.

The perspective that we propose is focused on the real activity of the user during situations of use and their lived experience. Taking into account their lived experience of these new situations means that we are interested not only in their rational and strategic conduct but also in their emotional reactions and in their affective motivations to act. For instance the users' affective relation to a specific risk, their emotional tolerance to uncertainty, or their feeling of trust/mistrust built towards the instruments, services, and co-actors of the use, are very important phenomena, which impact their decisions and actions during the use, but they are not enough taken into account.

The methodology is mainly based on specific techniques of interviews (also based on video recordings and diaries) and may be completed by some questionnaires focused on the most interesting processes. There is a limit to these interview methodologies which are the core of our research: they are time-consuming (because of in-depth analysis of the psychological processes of use) and focused on a limited number of subjects. Nevertheless they are very useful for orienting the design; for instance the in-depth analysis of how drivers react to the various instruments helping them to control the car autonomy during the driving situations allows us to re-orient the design adequately. It is not the case through questionnaires for instance; we could not ask precisely how people react in such or such situation. With diaries we can ask people to describe specific use cases but generally they do it quickly and without many details. It is much more complete when an interviewer helps the subject to describe a specific situation of use. The global objective is actually to understand better the user lived experience in order to develop adapted services and technologies.

Acknowledgment

We thank Jean-François Forzy (Renault) and Christian Licoppe (Telecom ParisTech) for their constructive comments on this methodological framework. We also thank Renault, the IMD (Sustainable Mobility Institute), and the French VeDeCoM Institute for financing and promoting the two PhD studies on innovative modes of mobility.

References

[1] S. Caroll, "The Smart Move Trail: Description and Initial Results", Technical Report: Cenex, 2010, available at: http://www.cenex.co.uk/LinkClick.aspx?fileticket=yUKAcRDJtWg%3D&tabid=60. [retrieved: march, 2013]

[2] P. Cocron et al., "Methods of Evaluating Electric Vehicles From a User's Perspective - The MINI EV Field Trial in Berlin", IET Intelligent Transport Systems, vol.5, issue 2, 2011, pp. 127-133, doi: 10.1049/iet-its.2010.0126.

[3] N. Pearre, W. Kempton, R. L. Guensler, and V. V. Elango, "Electric Vehicles: How Much Range is Required for a Day's Driving?", Transportation Research Part C: Emerging Technologies, vol. 19, issue 6, December 2011, pp. 1171-1184, doi: 10.1016/j.trc.2010.12.010.

[4] A. Barthès, "Première approche quantitative des processus de covoiturage dans les territoires", CITC, CERTU, Ministère du développement durable, 2009, available at : http://hal.archives-ouvertes.fr/hal-00391218/. [retrieved : march, 2013]

[5] R. Clavel and P. Legrand, Le Covoiturage Dynamique : Etude préalable avant expérimentation, Rapport d'étude, Centre d'Etude sur les Réseaux, les Transports, l'Urbanisme et les constructions publiques, 2009, available at : http://lara.inist.fr/bitstream/handle/2332/1463/CERTU-RE_09-03.pdf?sequence=1. [retrieved : march, 2013]

[6] T. Wang and C. Chen, "Attitudes, Mode Switching Behavior, and the Built Environment: A Longitudinal Study in the Puget Sound Region", Transportation Research Part A: Policy and Practice, vol. 46, iss. 10, December 2012, pp. 1594–1607.

[7] L. A. Suchman, Plans and Situated Actions – The Problem of Human-Machine Communication. New-York: Cambridge University Press, 1987.

[8] B. Cahour and P. Salembier, "The user phenomenological experience ; evoking the lived activity with « resituating interviews »", CHI 2012 Conference, May 2012, Austin, USA.

[9] A. Light, "Adding Method to Meaning. A Technique for Exploring People's Experience With Technology", Behaviour and Information Technology, vol. 25, iss. 2, 2006, pp.175-187.

[10] J. McCarthy and P. Wright, Technology as experience. Cambridge, MA: MIT Press, 2004.

[11] J.M. Robert and E. Brangier, "What is prospective ergonomics? A reflection and a position on the future of ergonomics", in Ergonomics and Health Aspects, HCII 2009, B.-T. Karssh, Eds. Springer-Varlag Berlin Heidelberg, 2009, pp. 162-169.

[12] B. Cahour, C. Nguyen, J.-F. Forzy, and C. Licoppe, "Using an electric car: a situated, instrumented and emotional activity", Proc. European Conference on Cognitive Ergonomics (ECCE 12), August 2012, pp. 22-28, doi : 10.1145/2448136.2448142.

[13] C. Nguyen, B. Cahour, J.-F. Forzy, and C. Licoppe, "L'inquiétant risque de panne : des instruments pour anticiper et des instruments pour réagir", Proc. 46è Congrès de la Société d'Ergonomie de Langue Française (Self 11), Sept. 2011.

[14] J. Birrell, K. Meares, A. Wilkinson, and M. Freeston, "Toward a Definition of Intolerance of Uncertainty: A Review of Factor Analytical Studies of the Intolerance of Uncertainty Scale", Clinical Psychology review, vol. 31, iss. 7, Nov. 2011, pp. 1198-1208, doi: 10.1016/j.cpr.2011.07.009

[15] K.L. Mosier and U. Fisher, "The Role of Affect in Naturalistic Decision Making", Journal of Cognitive Engineering and Decision Making, vol. 4, iss. 3, 2010, pp. 240-255, doi: 10.1518/155534310X12844000801122.

[16] http://www.carpooling.com/press/companypressmedia-kit/carpooling-without-borders/ [retrieved : march 2013]

[17] COVIVO SAS., Rapport d'étude, Expérimentation du Covoiturage dynamique, Entre le plateau du Vercors et l'agglomération grenobloise, 2011, available at : http://itinisere.fr/ftp/documents_FR/rapport-final-public_ecovoiturage.pdf, [retrieved : march 2013]

[18] JC. Ballet and R. Clavel, Le Covoiturage en France et en Europe : Etat des Lieux et Perspectives, Rapport de recherche, Centre d'Etude sur les Réseaux, les Transports, l'Urbanisme et les constructions publiques, 2007, available at : http://lara.inist.fr/bitstream/handle/2332/1453/CERTU-RE_08-01.pdf?sequence=1. [retrieved : march, 2013]

[19] S. Vincent, Les Altermobilités : Analyse Sociologique d'Usages de Déplacements Alternatifs à la Voiture Individuelle. Des pratiques en émergence?, Thèse Université de Paris 5, 2008, available at : http://tel.archives-ouvertes.fr/docs/00/33/16/59/PDF/theseSVINCENT.pdf . [retrieved : march, 2013]

[20] I. Richard, Facteurs et processus psychosociaux du changement pour l'adoption de comportements pro-environnementaux : le cas du covoiturage. Thèse de doctorat en Psychologie, Laboratoire de psychologie sociale (EA 849). Université de Provence – Université de Nîmes, 2011.

[21] D. M. Dorinson, D. Gay, P. Minett, and S. Shaheen,. "Flexible carpooling : exploratory study", Institute of Transportation Studies, Research Report UCD-ITS-RR-09-37, 2009.

[22] http://www.covoiturage.fr/

[23] B. Rajaonah, F. Anceaux, and F. Vienne, "Study of Driver Trust During Cooperation with Adaptive Cruise Control", Le Travail Humain, vol. 69, iss.2, 2006, p. 99-127, doi : 10.3917/th.692.0099.

[24] B. Cahour and J.-F. Forzy, "Does Projection into Use Improve Trust and Exploration ?", Safety Science, vol. 47, iss. 9, nov. 2009, pp. 1260-1270, doi:10.1016/j.ssci.2009.03.015.

[25] Groupe Chronos & BlaBlaCar, Trusted Online Communities: signs of a brighter future, Communication at Le web, Dec. 2012, available at: http://www.betrustman.com/. [retrieved : march, 2013]

[26] P. Vermersch, L'Entretien d'Explicitation. Paris : ESF, 1994.

[27] M. Maurel, "The Explicitation Interview: Examples and Applications", Journal of Consciousness Studies, vol. 16, iss. 10-12, Oct-Nov. 2009, pp. 58-89

[28] B. Cahour, "Discomfort, Affects and Coping Strategies in Driving Activity", Proc. European Conference on Cognitive Ergonomics (ECCE 08), Sept. 2008, pp. 91-98, doi: 10.1145/1473018.1473046.

[29] N. Depraz, F. Varela, and P. Vermersch, On Becoming Aware. A Pragmatics of Experiencing. Amsterdam: Benjamin. 2003.

[30] http://www.avego.com/

DSM of Electric Vehicles using Future Internet

Balancing the grid in cases of unplanned events causing frequency instability

Jesse Kielthy, Anthony Kiely, Cathal O'Connor, Miguel Ponce de Leon
TSSG
Waterford IT
Waterford, Ireland
{jkielthy, akiely, coconnor, mpdl}@tssg.org

Mark Daly, John Howard
ESB eCars
ESB
Dublin, Ireland
{mark.daly, john.howard}@esb.ie

Jonas Fluhr
FIR
RWTH Aachen University
Aachen, Germany
jonas.fluhr@fir.rwth-aachen.de

Matthias Sund
Alcatel-Lucent AG
Bell Labs
Berlin, Germany
matthias.sund@alcatel-lucent.com

***Abstract* — Transitioning to a more automated grid requires changes and enhancements to grid operations, to the network structure and to end-user interaction. Concurrently, a desire to integrate renewable power sources into the grid imposes significant strains on existing electricity infrastructures and can lead to critical volatility in the grid frequency as a result of these unreliable supply sources. Of all the elements of frequency control available to a Transmission Systems Operator (TSO), by far the most valuable is the availability of an autonomous 5-15 second response window. In this paper, we demonstrate the feasibility of using future internet technologies to balance the load on the grid in cases where unplanned events e.g., a drop in Renewable Energy Supply (RES), has caused fluctuations in grid frequency. This is done by, but not limited to, remotely controlling the load drawn by the domestic Electric Vehicle (EV) charge points.**

Keywords – demand side management; electric mobility; electric vehicles; renewable energies; future internet; smart energy

I. INTRODUCTION

The European Commission outlines ambitious targets for "raising the share of EU energy consumption produced from renewable resources to 20%" [1]. In Ireland, this is even more ambitious, with a target of "40% electricity consumption from renewable sources by 2020" [2]. Due to the abundance of wind in Ireland (see Figure 1, where dark grey indicates high wind speeds), this will be the predominant source of renewable energy to meet these targets [3].

However, this desire to integrate renewable power sources (other proposed sources include solar, tidal) into the grid imposes significant strains on existing electricity infrastructures. Figure 2 illustrates that short term fluctuations in wind energy supply are random, frequent and, though weather modeling plays a crucial role in predicting wind patterns and movements, it is still extremely difficult to accurately forecast this supply.

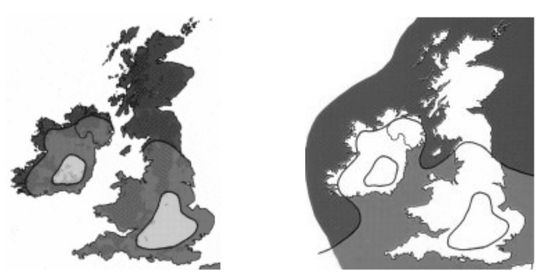

Figure 1. On/Offshore Wind Availability in Ireland

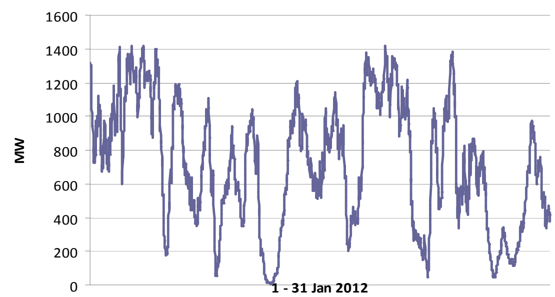

Figure 2. Wind Power Ireland - Jan 2012

A continuous balance between power generated and power consumed is required to maintain a constant, synchronous grid frequency (in Europe this is 50Hz). Any imbalance in power (generated or consumed) can result in a deviation in this frequency which, in turn, can adversely affect the transmission and distribution of electricity around the grid. Frequency control can ensure that the system remains within acceptable limits, and one such element of frequency control is *Demand Side Management* (DSM), which involves controlling the power demand so that it tracks the power supply.

Electric Vehicles (EVs) are suitable candidates for DSM due to their charging power demand of 3.6 kW (single phase at 16A) on a standard residential plug. For every 1000 Electric Vehicles (EV) charging on the grid, the load drawn is approximately 2.5-3.5MW. By reducing the charge rates of EV's on the grid by just 50% during the initial minutes of the disturbance, a grid can be stabilized while spinning reserve is ramped up to take up the slack. Here, generators are available to provide power typically within 10 minutes. These reserves are used when another generator on the system goes down or deactivates unexpectedly [4]. The effect on EV charging is negligible over the course of a 6-8 hour night-time charging period.

Charging independent of external EV requirements (i.e., non-battery related) is known as *smart* or *intelligent* charging. Several investigations have been conducted with respect to

 ISBN: 978-1-61208-282-0

different external requirements. Most of these investigations focus on charging in dependence of availability of Renewable Energy Supply (RES) in the grid [5][6], others investigate coherence with driving profiles [7][8]. External requirements such as local or global grid parameters (frequency, voltage) are mainly considered under the umbrella of the potentially bi-directional power flows called Vehicle-to-Grid (V2G) [9-12] or by simulations [13]. Therefore, the following scenario focuses on uni-directional power-flows in dependence of grid parameters. It leverages Future Internet (FI) technologies and uses a testbed approach instead of pure simulations.

In order to allow for a scenario where EVs support grid stability as part of DSM, several general requirements are to be fulfilled, such as secure and fast communication, sufficient availability of EV (time and place) as well as effective market integration. These requirements where considered when defining the scenario (section II) and designing the testbed (section III).

Section II describes the DSM scenario and provides further background details about the issues that have given rise to this work; Section III details the connectivity requirements, the critical response requirements of the scenario and testbed architecture; Section IV describes technical implementation of a future internet frequency response framework; Section V outlines some of the challenges that are yet to be addressed; and finally, Section VI offers some conclusions.

II. SCENARIO

In day-to-day operations, generating stations can experience protective load shedding events. These events are protection actions which de-rate the generated power of a turbine until a stable operating condition is reached. The load shedding takes place under a pre-determined ramp rate (typically 3MW/sec). As generation is lost, this requires a balancing of the load in order to stabilize the grid.

The speed of reaction in applying this load balancing is crucial. Direct Unit Trips (DUT) are available which can drop generation by hundreds of MW instantly – for example, wind turbines can shut down in blocks due to gusting winds, dropping 10's of MW generation from the grid instantly. Generators who experience protective load shedding send signals to the grid controller. These signals notify of imminent events. Instantaneous disturbances will first be identified by a frequency drop.

Of all the elements of frequency control available to a Transmission Systems Operator (TSO) (apart from DUTs), by far the most valuable is the availability of an autonomous 5s-15s response which constitutes *Primary* frequency control. Following that, a secondary (15s-900s) and tertiary (900s+) response period provides the operator with an opportunity to control additional resources in order to restore stability to the grid as well as to react to changes in the anticipated load pattern. Figure 3 shows the system frequency profile as it is restored through these periods.

The grid is designed to absorb limited frequency fluctuations (positive and negative). For example, if the frequency deviates from 50Hz to 49.8Hz, then the system will continue to operate as normal.

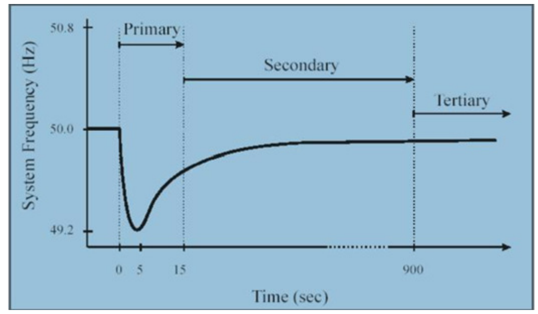

Figure 3. Frequency control phases

The response to more critical frequency deviations can be considered in a stepwise manner. Table I presents the nominal sliding scale of response to frequency fluctuations (this was defined for the purposes of testing, though can be considered as indicative of a step-wise response to frequency fluctuations).

TABLE I. SLIDING SCALE OF RESPONSE

Frequency	Reaction
50 to 49.8 Hz	• No reaction
49.8 to 49.5 Hz	• Reduce current 25 % (5 min)
49.5 to 49.3 Hz	• Reduce current 50 % (5 min)
Below 49.3 Hz	• Stop charging (10 min)
Post-Stability	• Ramp back for 15 minutes

The scenario presented here uses Future Internet (FI) ICT to provide a smarter, more efficient, autonomous Demand Side Management system. This system empowers operators to manage the demand for energy across the network – in this case, by limiting or stopping the load drawn by EVs. This is done by remotely controlling the Electric Vehicle Supply Equipment (EVSE) i.e., the EV charge point. EVs represent a special type of load in this case, whereas DSM is not limited to controlling a particular demand, but may utilize additional controllable loads, e.g., air conditioning systems. In doing this,

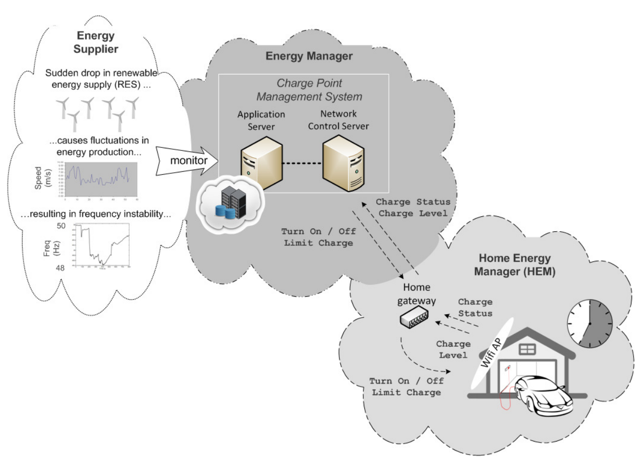

Figure 4. DSM of EV charge points using Future Internet

 ISBN: 978-1-61208-282-0

TSOs can offset decreases in energy supply, and any corresponding grid frequency fluctuations, by regulating the load being drawn down by, e.g., EVs as they are charging.

Figure 4 is a storyboard that illustrates the basic setup of the scenario – (from top left to right) the Energy Supplier has ever-increasing volumes of RES to be supported on the grid. RES generation can vary dramatically thus causing fluctuations in the overall energy supply and, as a consequence, cause grid frequency instability. The grid frequency is continuously monitored via a high-capacity management system. If the grid frequency fluctuates, then the Operator can use the energy management system to offset the drop in supply by controlling the load drawn down by the EVSE via the home energy manager (HEM), say, in a similar fashion to those reactions outlined in Table I (these are illustrative responses, rather than standard).

III. SCENARIO ARCHITECTURE

Once the grid frequency simulation is initiated, it is assumed the grid frequency is becoming unstable. A *Grid Event* is then recognized and acted upon by the TSO. Following that, real-world management and control of the load on the network (e.g., electric vehicles) demonstrates the feasibility of the use case by allowing the TSO to stabilize the grid.

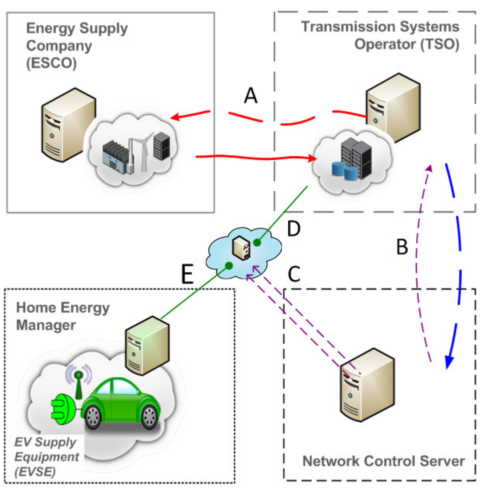

Figure 5. Connectivity diagram for testbed

The three main entities involved in this scenario are:

- *Energy Supply Company (ESCO):* trades on the Energy Market. Expected to be included in this trading is the sale of spinning reserve, a reserve that is very quickly available (this is currently not possible however is likely to be possible in future dynamic markets). The quantity of spinning reserve available is dynamic and regularly sent to the Transmission System Operator (TSO).
- *Transmission Systems Operator (TSO):* operates the transmission grid.
- *HEM:* monitors and manages the energy consumption with the Home Area Network (HAN). The EVSE is an element of the HAN and, as a result, can be remotely controlled and managed via the HEM.
- *Network Control Server:* establishes network paths, subject to specific requirements, between the TSO and the HEM

As illustrated in Figure 5, this scenario makes use of VPNs and network API's to dynamically configure links, thus ensuring that end-to-end connectivity is available. The main interfaces are:

A. From the *ESCO* to the *TSO* – a bi-directional interface that allows frequency notifications to be sent from TSO to ESCO, and tradable power information from ESCO to TSO.

B. & C. From the *TSO* to *Network Control Server* – the TSO instructs the Network Control Server to initialize the process to establish links between the TSO and HEM. The Network Control Server then uses the Network API to dynamically configure the various interfaces i.e., to the TSO and HEM.

D. & E. From the *TSO to the HEM* – connectivity is verified so that an end-to-end connection is available between the TSO and the HEM. This enables the TSO to remotely control the load being drawn down EVSE via HEM.

IV. IMPLEMENTATION

The overall operation of the end-to-end scenario is captured in Figure 6, where the different stakeholders (ESCO, TSO, HEM and EVSE) are encapsulated in an *Autonomous Frequency Response Framework.*

This figure illustrates the interaction between the different components that, together, help deliver an end-to-end demand side management solution. The framework is comprised of both simulated and real-world elements and the algorithm is designed so that, as the frequency breaches the thresholds defined by Table I, a proportional response is implemented to reflect the severity of the respective breach.

(1) The *Device Communication Layer* is a bi-directional component that takes in the data from various sources e.g., from the grid, electric vehicle or from the user, while at the same time it can affect change by communicating the required response commands to the end-user devices i.e., EV charge point

(2) The *Service Management* component receives all of the necessary information from the various sources in the system, models the service in order to determine whether it is behaving appropriately or not, and makes the decisions to affect change by defining the correct responses to be implemented.

Following that, the development environment and related testbed was configured as in Figure 7. The EVSE was connected to a WIFI access point. The WIFI network is managed by a HEM and this allows the TSO to instruct the HEM to stop / start / control the load of the EVSE.

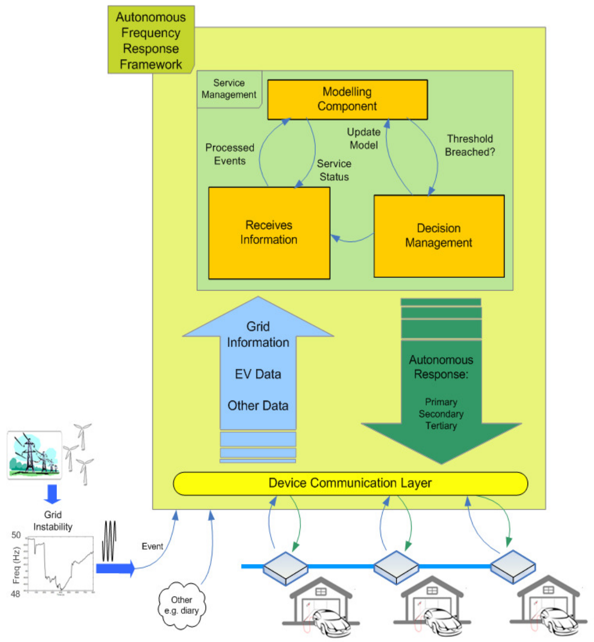

Figure 6. Autonomous frequency response framework

The TSO supports a service that provides the frequency data and a timestamp from the ESCO. When the TSO receives this request, it checks to see if the timestamp is greater than the previous timestamp. This is to ensure that the TSO has received a new frequency value. If the timestamp is greater, it proceeds with its work and, if it is not, it informs the user of this.

The TSO checks the received frequency value as according to thresholds outlined in Table I.

So if, for example, the frequency is in the 49.8-50Hz range, the TSO contacts the Home Energy Manager (HEM) to find out the current status of the charge point (on/off).

For the HEM to get this status information it has to communicate with the charge point (CP) through a Telnet session. Telnet is a network protocol that can be used to enable devices in separate locations to remotely connect. Initially, when the TSO sends a request to the HEM, it opens up a telnet session to the charge point. The HEM parses the data that it receives from the CP so that it can see the current status of the CP. The status information is then returned from the HEM to the TSO. If the CP is currently on it sends a message from the TSO to the ESCO stating that the CP is on. This information is then displayed as the log entry (see Figure 8).

When the frequency is below 49.3Hz, the TSO sends a request to the HEM for an updated status message. If the HEM sends a response to the TSO stating that the CP status is on, the TSO will send a request to the HEM to turn off the CP. The HEM will open up a session with the CP and send a command to turn the CP off. The HEM will then send a response back to the TSO stating the current status (off) of the CP. This current status of the CP and the frequency is sent from the TSO to the ESCO. This information is then added to the.

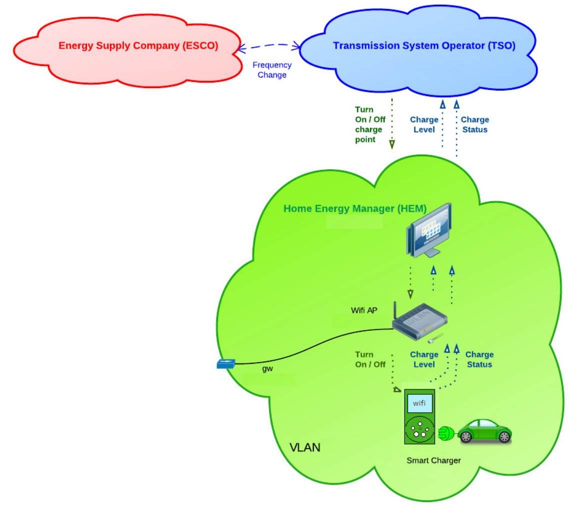

Figure 7. Testbed infrastructure

When the frequency is above 49.3 Hz, the same process as above takes place where the HEM sends an "on" command to the CP which will turn the CP on again. The new status of the CP and the frequency will be recorded as a log entry.

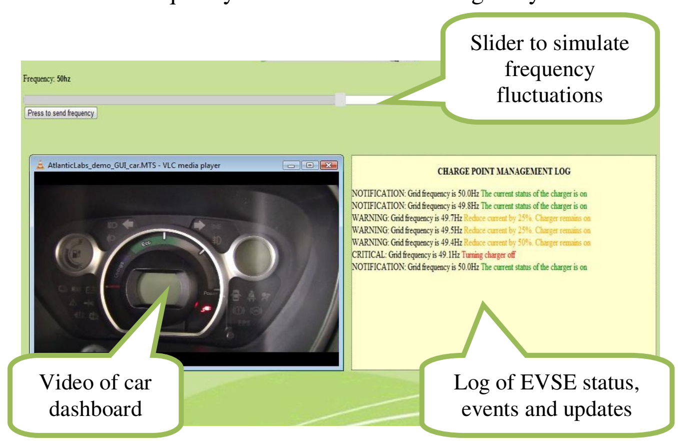

Figure 8. DSM demo interface

V. CHALLENGES

A. Scalability

With a target of 10% of all Irish vehicles on the road to be electric by 2020 [2], the demand side management application would potentially have cater for up to 250,000 electric cars.

Web services may not be a solution that scales efficiently for a large scale deployment of a management solution such as this and, though using web services has provided valuable insights to the design and engineering of the solution, further investigations are required to evaluate the most effective technology. Potential alternative technologies may include the use of FI-WARE [14] platform and technologies to deliver generic capabilities (e.g., QoS, connectivity, security), upon

 ISBN: 978-1-61208-282-0

which specific components (e.g., smart chargers) can be developed and integrated.

B. *Extendibility*

As well as EVs, other *controllable* loads ought to be considered for this application – for example, smart public street-lighting, televisions and fridge-freezers within the HEM, etc. Furthermore, it may be useful to consider the aggregation of these loads e.g., by towns, cities, regions, so that the TSO is able to apply a regional demand side solution to a regional supply problem.

C. *Speed of Response*

Due to the severe impact of a frequency drop on the energy grid, communications to the cars must be prioritized over delay tolerant Internet applications. In this case, the telecoms network should support contractual service level agreements with smart grid applications and should have interfaces to the network to actively manage its capacities and services in real time.

D. *Security*

There are a number of security considerations to this research - consideration for user identification and verification, anonimization of information, identity management and secure data handling will need to be considered. Secure communication tunnels between endpoints (e.g., TSO and HEM) will encrypt the data, ensure privacy and prevent snooping and spoofing.

E. *User incentivisation*

It is envisaged this scenario can deliver dual benefits to both the consumer and the grid operator. For the former, an incentivisation scheme could ensure that users who subscribe to the event scheme could partake of a loyalty system and avail of having potential kWh credits or reduced kWh tariffs while interruptible. Operators could benefit from increased acceptance of renewables on the grid and could additionally offset grid penalties and reward loyal customers who opt-in to allow them to control their charge points to ensure grid stability.

Not all users will be able to participate in this scenario – for example, an on-call doctor would not like to have the charging of their car interrupted. However, it is important to get users to opt-in to this scheme and one way to do this is through incentivisation e.g., if a user partakes in this scheme and their charge is interrupted, say, twice in 3 months then the energy provider could compensate them through reduced tariffs on their next bill.

The transfer of benefit data and loyalty benefits will need to be exchanged and redeemable. All quantities such as kW's and credits will require to be validated for audit and transparency purposes.

VI. CONCLUSIONS

Frequency control can be called upon for a variety of conditions ranging from a gradual change in load levels over time to a sudden loss of generation or step increase in demand.

The solution presented here, while demonstrated using electric vehicles smart charge points, can utilize other interruptible loads to gain greater advantage of demand side management – including additional loads from within the home or through the aggregation of loads within a region in order to provide a localized solution.

Providing grid operators with the real-time ability to stabilize the grid frequency by controlling the demand can become a critical tool for the future energy consumption of EV in the smart grid.

ACKNOWLEDGMENT

This work was undertaken as part of the FINSENY project and funded by the EU Future Internet – Public Private Partnership (FI-PPP) programme under the Grant Agreement number 285135. The authors would like to acknowledge the invaluable insight of FINSENY colleagues.

REFERENCES

[1] E. Morgera, K. Kulovesi, M. Munoz "The EU climate and energy package" Social Science and Research Network (SSRN), Nov. 2010, http://dx.doi.org/10.2139/ssrn.1711395

[2] Department of Communications, Energy & Natural Resources (DCENR) Ireland "National Renewable Energy Action Plan IRELAND" Nov. 2009

[3] Risø National Laboratory for Sustainable Energy "European Wind Atlas"

[4] International Electrotechnical Commission (IEC) "Grid Integration of large-capacity Renewable Energy Sources and use of large-capacity Electrical Energy Storage" Oct. 2012

[5] M. Agsten, S. Schlegel, S. Bohn, D. Westermann, X. Pfab "Determinants of successful management of charging Electric Vehicles" Smart Grid VDE Congress, Stuttgart, 2012

[6] D. Dallinger, J. Link, F. Kley, M. Wietschel "Variable tariffs for demand response with grid-connected electric vehicles and their contribution to integrate intermittent renewable generation" Smart grids and E-mobility, 2nd European Conference on Smart Grids and E-Mobility, Oct. 2010, ISBN: 978-3-941785-14-4

[7] F. Kley, D. Dallinger, M. Wietschel, "Optimizing the charge profile - considering users' driving profiles" Unpublished, Sustainability and Innovation No. S 6/2010, Frauenhofer ISI

[8] J. Fluhr, K-H. Ahlert, C. Weinhardt "A Stochastic Model for Simulating the Availability of Electric Vehicles for Services to the Power Grid" 43rd Hawaii International Conference on System Sciences (HICSS). 2010 http://dx.doi.org/10.1109/HICSS.2010.33

[9] W. Kempton, J. Tomic, "Vehicle-to-grid power fundamentals: Calculation capacity and net revenue" Journal of Power Sources. Vol. 144 (2005) 268–279

[10] W. Kempton, J. Tomic, "Vehicle-to-grid power implementation: From stabilizing the grid to supporting large-scale renewable energy" Journal of Power Sources. Vol. 144 (2005) 280–294

[11] W. Kempton, J. Tomic, "Using fleets of electric-drive vehicles for grid support" Journal of Power Sources. Vol. 168, Iss. 2 (2007) 459–468

[12] D. Dallinger, D. Krampe, M. Wietschel "Vehicle-to-Grid Regulation Reserves Based on a Dynamic Simulation of Mobility Behavior" IEEE Transactions on Smart Grid, Vol. 2, No. 2, June 2011

[13] A. Rautiainen, S. Repo, P. Järventausta "Using Frequency Dependent Charging of Plug-in Vehicles to Enhance Power System's Frequency Stability" European Conference on Smart Grids and E-mobility, Würzburg, Germany

[14] FI-WARE http://www.fi-ware.eu/

A Smart Waste Management with Self-Describing objects

Yann Glouche
Paul Couderc
INRIA, Unité de Recherche Rennes-Bretagne-Atlantique
Campus de Beaulieu, Rennes, France
email: {yann.glouche,paul.couderc}@inria.fr

***Abstract*—Radio Frequency Identification (RFID) is a pervasive computing technology that can be used to improve waste management by providing early automatic identification of waste at bin level. In this paper, we propose a smart bin application based on information self-contained in tags associated to each waste item. The wastes are tracked by smart bins using a RFID-based system without requiring the support of an external information system. Two crucial features of the selective sorting process can be improved using this approach. First, the user is helped in the application of selective sorting. Second, the smart bin knows its content and can report back to the rest of the recycling chain.**

Keywords-green IT; waste management; recycling chain; RFID; NFC; QR code.

I. INTRODUCTION

Waste management is an important requirement for ecologically sustainable development in many countries. Efficient sorting of waste is a major issue in today's society. In Europe, the consumer society has led to an ever increasing production of waste [1]. This is a consequence of the consumer's behavior, and worsened by packaging. In [2], it is shown, that the production of waste reaches almost 1.2 kg/day/inhabitant in western Europe. Paradoxically, the same consumers who are very sensitive to environmental protection are often reluctant when it comes to have more land-filing or more incinerators. Therefore, waste should be disposed and treated properly to reduce environmental impact.

Waste management services are becoming an important market, for which the waste collection process is a critical aspect for the service providers [3], [4]. The main goals are the following :

1) Reducing waste production
2) Ensuring that wastes are properly disposed
3) Recycling and re-using disposed products

To achieve these goals, regulations and taxes are being implemented to favor virtuous behaviors. In particular, to reduce the production of waste, there is an increasing trend towards individual billing, where people are charged depending on waste quantity disposed.

Selective sorting is another approach, which is often implemented to improve recycling and reduce the environment impact. The importance of resources and energy saving is another argument to manufacture recyclable materials.

The sorting of wastes must be implemented as early as possible in the chain to increase the quantity of valuable recyclable materials. The use of pervasive computing technology such as Radio Frequency Identification (RFID), and sensor networks offer a new way to optimize the waste management systems.

In recent years, we have seen increasing adoption of the radio-frequency identification (RFID) technology in many application domains, such as logistic, inventory, public transportation and security. Essentially, RFID makes it possible to read digital information from one or several objects using a reader at proximity of the objects, enabling automatic identification, tracking, checking of properties, etc. It is predicated that RFID could replace barcode and attached to most products by manufacturers and/or retailers. In this perspective, RFID would be an important opportunity for waste management, as RFID tags could be used to improve current waste management processes.

This paper proposes a method to improve the quality of selective sorting. This approach is based on local interactions to track the waste flow of a city. Each waste is detected by information properties stored in a RFID tag associated to it. At each step where wastes are to be processed the RFID tags are read in order to provide the relevant information. This process improves the sorting quality of recyclable products. We assume organic wastes products are not recycled and hence RFID tags are not attached to it.

Without using an external information system, RFID can improve the selective sorting quality. The information stored in each tag associated to a waste can be used to help the user in the sorting process, and to analyze the content of a bin.

This article is organized as follows. The next section outlines the architecture used to process the waste flow in our waste management system. The third section presents a tagged (or self "describing") waste approach. The fourth section details our RFID system to help the individual sorting of the wastes, while the fifth section discusses some related works. Finally, Section VI concludes the paper.

II. WASTE FLOW AND GLOBAL ARCHITECTURE OF THE WASTE MANAGEMENT SYSTEM

The waste management architecture we consider is built around several elements: waste items, domestic bin, trash bags, collective containers and collecting vehicules. The waste flow

 ISBN: 978-1-61208-282-0

starts from the waste items and the domestic bin to end in the collecting vehicules. We now describe each of step in the waste flow and how elements interact.

A. Wastes description

The presented management system is based on a self-describing approach of each waste. We propose to associate digital information to each waste to ensure an appropriate treatment of each item. This is a key point of this approach.

In the selective sorting process, the type of a waste item is identified by its main component. For example, a plastic bottle is identified as a plastic waste, and a cardboard box is identified as a cardboard waste. In the presented approach, each self-describing waste carried digital information about its type. Other properties of the waste are interesting for the collection process of the wastes. For example, the weight of each wastes can be used to estimate if a bin is full, or empty. Without using measurement sensors, the weight data of a waste item can be stored in digital information attached to it, making itself describing.

B. Wastes identification

The user is the principal element of the selective sorting process. Based on this observation, our waste management system proposes some pervasive assistance for the selective sorting process. Then, the waste flow presented in Figure 1, begins at the user level where the trash is generated. As it is shown on the top of Figure 1, we propose to favor a behavior of the users: by indicating the appropriate bin for a waste, or more directly, by opening the lid of the bin corresponding to the type of the waste.

C. Trash bag

To ensure an appropiate treatment, the knowledge of the type of wastes contained in a trash bag is crucial. As for the wastes, it is also possible to associate several properties of each trash bag: for example, the owner of the trash bag, and the number of items in the trash bag can also be considered. In the prototype presented in the next sections, some digital information about the total weight of the trash bag, its content and the number of items contained in the trash bag are physically associated to each trash bag. In this prototype, some digital information is also associated to identify the owner of a trash bag: the interest is to identify the waste production of each consumer. This information defines an analysis report associated to each trash bag.

The analysis report stores some important information for the selective sorting process. The information stored in the analysis report is to determine whether the trash bag could be accepted. In Figure 1, this analysis report is transmitted to the collective container, when a user brings a new trash bag.

D. Collective container

In our waste management system, each collective container is associated to an embedded computing system which processes the data of the analysis report of each trash bag, making it a smart bin. When a new trash bag is added in a collective container, the analysis report is read.

Considering the type of wastes contained in a trash bag, a collective container determines whether it could accept a trash bag or not. For example, a collective container collecting only plastic wastes can stay closed when a user brings a trash bag containing the cardboard objects: it would only be opened for a bag of plastic wastes. If the trash bag is accepted, the smart bin stores some information about the content and about the owner of each trash bag. Then, the content of a collective container is iteratively updated as a new trash bag is added. The information stored by the collective container is transmitted to the truck during the collection by using a local connection, as it is presented on the bottom of Figure 1. At this step, the errors of the selective process can get transmitted. Among the collection of wastes, the highly polluting wastes which are not placed in the appropriate container, are detected: for example, it becomes possible to detect a battery placed in the container dedicated to plastic waste.

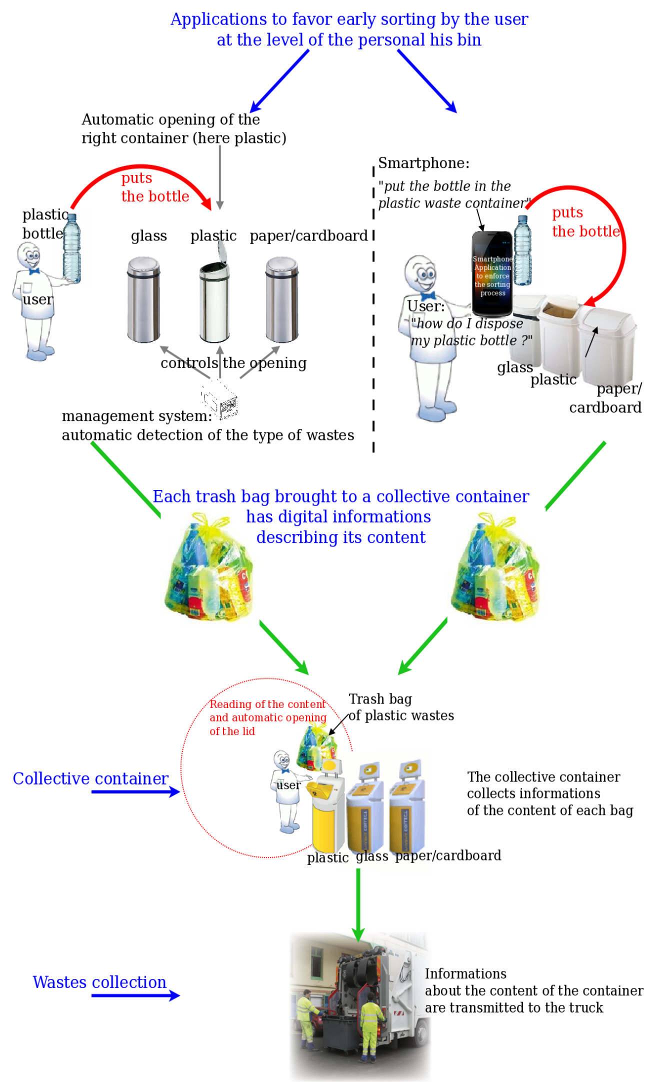

Figure 1. Waste flow and global architecture of the system.

 ISBN: 978-1-61208-282-0

Considering this waste flow, we now present a system based on RFID technology to implement this waste sorting process.

III. A SMART WASTE APPROACH

The *smart waste approach* consists of associating a physical waste with digital information. In our approach, information associated to a waste can be stored in a QR code or in a RFID tag memory. Using QR codes does not introduce an additional cost. However, QR code requires the object to be in line of sight. Unlike this technology, the RFID tags can be read without requiring a precise position relative to the reader during the reading operation. The UHF tags, are used increasingly in the supply chain management and can be easily read at a distance of five meters from the reader antenna. In this context it is easy to envisage a widespread deployement of the RFID tags on each manufactured product. This is an important advantage for using RFID technology in the waste management domain.

The tagged waste concept uses the data banks memory of a tag to store information about each waste associated to the tag. The tag memory is not used to store an identifer of the waste in an external database, but the information describing the associated waste is directly stored in the associated tag. A connection to an external database is not required to have some information about the smarte wastes. Only a RFID reader is required to read the information of a smart waste. Figure 2 presents a smart waste composed of a plastic bottle associated to a RFID tag which stores the data describing the bottle as a plastic object.

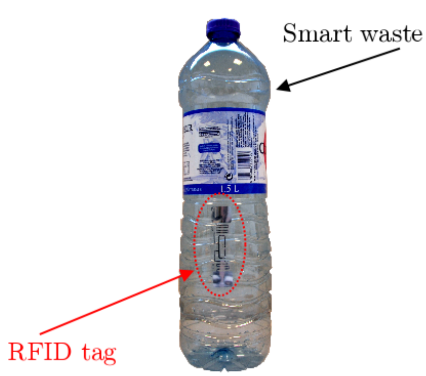

Figure 2. An example of a smart waste.

A RFID tag contains data banks for the users applications. The memory size of data banks is limited. For example, an UHF tag ALIEN ALN-9640 Squiggle shown in Figure 3 can store 512 bits of information.

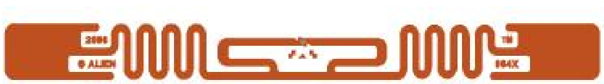

Figure 3. The ALN-9640 Squiggle Alien tag.

In [5], the classification of type of wastes is proposed. In this classification, each type of waste is associated to an identification number. Taking examples from everyday life:

- the cardboard is associated to the reference 200101,
- the glass is associated to the reference 200102,
- the plastic is associated to the reference 200139.

The smart waste concept proposes to use the classification [5], to store the reference number representing the type of the waste in memory blocks of each tag associated to a waste. As it is shown in Figure 4, our prototype also saves in the tag memory of each smart waste, the weight (represented by a measure in grams, encoded in hexadecimal) of the waste associated to the tag.

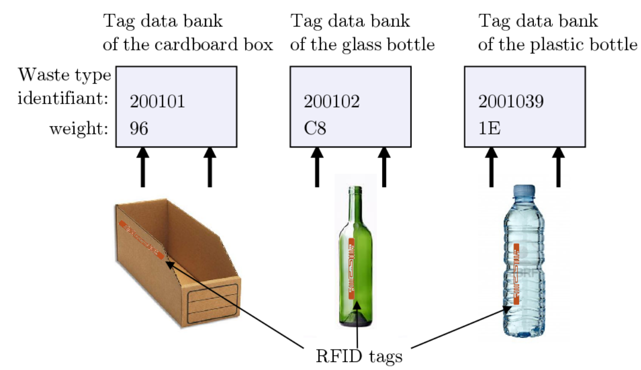

Figure 4. Representation of the information in the tag memory.

The weight encryption presented in Figure 4 is a way to store directly the description of each waste directly in the associated tag.

IV. A RFID WASTE SORTING SYSTEM

In this section, we describe the step of the domestic collection of the wastes. The presented approach proposed a smart bin which produces smart trash bags. At the end of this waste flow, the collective smart bin is presented.

A. Individual smart bins

At the first step of our waste sorting system, the information contained in the RFID tag associated to each smart waste is used to help the people discarding an object in the appropriate container. Here, the main goal is to reduce the sorting errors when someone does not know which is the right container, or mistakenly discards the object in the wrong one. It is also help people to learn the selective sorting rules applied locally. The smart bin system uses the self-describing approach of smart wastes to improve the selective sorting quality.

The description of smart wastes is stored in a RFID tag physically associated to each smart waste. Using a RFID reader, the smart bin reads the RFID tag attached to each smart waste to determine the appropiate treatment. Let's consider the example of someone who wants to discard a plastic bottle in a bin. He puts the bottle near a smart bin as it is shown on Figure 5. When the plastic bottle is in the antenna area, the

 ISBN: 978-1-61208-282-0

tag associated to the bottle is detected. The data stored in the tag is read to determine the appropriate procedure to discard the bottle. If the bin accepts plastic objects, then the system opens the lid of the bin. Otherwise, the system keeps closed the lid of the bin.

Note that it is also possible to control the opening of several containers using a single RFID reader. Figure 5 presents a prototype of a selective bin. In this approach, a management system connected to a RFID reader uses the data stored on waste tags to open the correct containers. In this example, when someone want to discard a pastic bottle, the container for the plastic wastes is opened by the management system. On Figure 5, only the lid of plastic container will be opened, all other lids will remain closed.

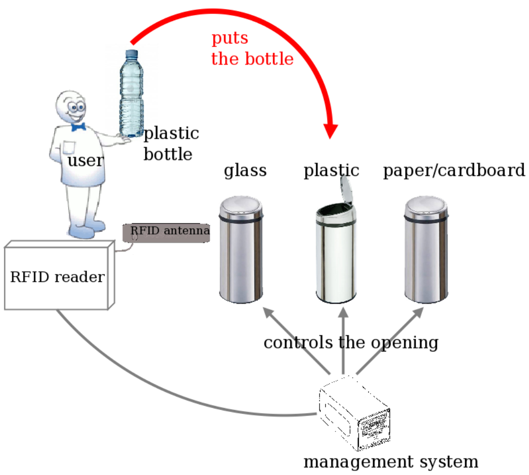

Figure 5. A RFID based selective bin.

This approach assumes that the management system tracks the information of the wastes that are discarded in each container of a selective bin. When a waste is discarded in the container, the management system updates the memory inventory for this type of waste. In this way, undesirable wastes for a given container are either rejected or tracked, depending on the choosen policy for handling undesirable wastes.

The scanning of products is done itemwise to ensure a complete reliable reading process.

Figure 6 presents a prototype of a smart bin based on UHF RFID tags and a UHF RFID reader which implements this approach.

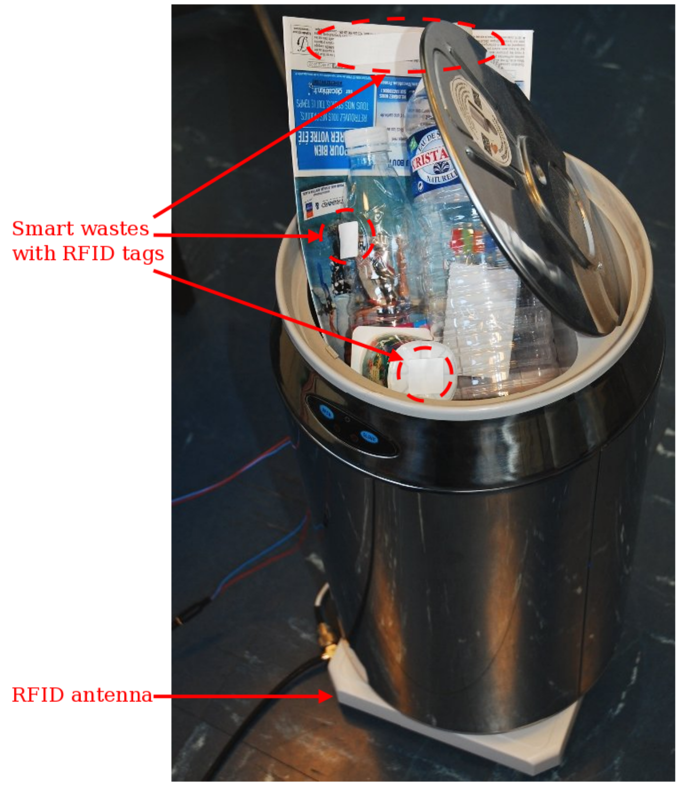

Figure 6. An individual bin using the RFID technology.

UHF RFID technology is already used in the supply chain management systems. In this context, a UHF tag is placed on the packaging of each product at the begining of its lifecycle. Since the UHF tag is already attached on the packaging of each product for the supply chain management process, we are interested to reuse the tag and its technology in our smart bin approach.

B. Use of QR codes technology for a cheaper approach

The passive UHF RFID tags are very cheap, ranging from \$0.25 to \$0.40 per tag. However, the price of a UHF RFID reader is still expensive (around \$2000). The current cost of the RFID reader can be a important issue for widespread deployment of the RFID technology in the smart bins of the households. We introduce here a cheaper solution using QR codes technology that would allow an early adoption of some of the concepts and applications presented previously. This approach is based on the NFC sensor embedded in the smartphone of the users.

This alternative approach assumes that every waste is associated to a QR code describing its type. The mobile application maintains in its memory the current inventory for each type of collected wastes (for example, 3 inventories if there are 3 types of collected waste). Waste disposal would require users to scan each item, allowing the mobile application to update the current inventory for this type of waste in phone's memory. Some other waste properties, such as weight, could also be collected at this step.

 ISBN: 978-1-61208-282-0

A smartphone is a small, low-cost, mobile computer. Moreover, most smartphones now embedd a camera enabling them to read bar codes or 2-dimensional QR codes (also known as "flash codes"). A first step in the solution would consist to scan a QR code (or bar code) associated to a product, and to use this information for giving a sorting instruction to the smartphone of the user. As in the approach of the individual RFID bin presented in section IV-A, it is also important to report the actions of the user to the waste collecting chain.

On figure 7, a user wants to drop a plastic bottle. He scans the QR code associated to bottle. The properties associated to the bottle are added to the inventory of the plastic container that is stored in the smartphone's memory.

Figure 7. Reading of a QR code associated to a waste.

Obviously, reading QR code is less convenient than RFID reading. In addition, in this approach the opening of the lid is also not controlled by an automatic system. However, this approach allows the deployment of the rest of the chain without requiring the smart bins presented in secion IV-A inside each home. Beside being cheaper, the mobile application also provides helpful support to the user regarding the selective sorting rules in application.

Like the individual bin presented in section IV-A, the management system of the collective bin tracks wastes properties as they are disposed. When a smart trash bag associated to a RFID tag is dropped in the collective container, the management system updates the collective inventory according to the new bag's content. Prevention of sorting errors is also possible, provided that the user actually fills his trash bags according to what he scans.

We don't rely a network connection on the bin instead it is the waste bag itself which will store the waste inventory. As we will see in next section.

C. *Smart trash bag*

In the individual selective sorting point like a smart bin in the kitchen of a user, the wastes are not directly deposited in the container of the bin. Every user uses a trash bag, which will be dropped to a collective container, or put at the entry of every households for being collected by the service provider.

The *smart trash bag concept* is smart in the sense that the waste management infrastructure (bin, truck) will be able to check its contents. A smart trash bag is a trash bag associated to a RFID tag, as it is shown in Figure 8. The tag associated to a smart trash bag, offers a memory space to store some information about the contents of the trash bag: type of wastes, number of items. The RFID tag associated to the smart trash bag also stores some information about its owner: name, adress, etc.

Figure 8. A smart trash bag.

Writing data in the tag associated to the smart trash bag about its content is very simple: for each new waste added, it is identified by reading the waste tag; then, the trash bag content is updated by writing in the trash bag's tag with the updated information about its content. This approach enables the tracking of trash bag content. Various information can be reported: the type and quantity of wastes contained in the bag, total weight of the content, and the interactions between the wastes. In this approach, it is assumed that the management system ensures that all the wastes of a container belong to the same type. Then, it is just necessary to store the expected type of wastes in the analysis report. The weight of the smart bag is estimated by considering the weight of each smart waste contained in it. When a smart waste is added, its weight is read in the tag memory of the smart waste. The weight of the smart trash bag is refreshed by adding the weight of this smart waste to its current weight. The weight is computed when a smart waste is added. This iterative process uses the information stored in the tag associated to each smart waste. This approach is totally autonomous and based on the information stored in the tags associated to each smart waste. A connection to an external information system is not required to obtain the information associated to each waste.

As it is illustred in Figure 9, the information stored in the tag associated to the smart trash bag, are encoded by a

 ISBN: 978-1-61208-282-0

sequence of bytes. The storage of the identifier of the owner uses three bytes. Using the classification of wastes [5], the type of wastes is stored on six hexadecimal digit: three bytes. The number of waste items is stored on one byte. The weight (in gram) of the content is stored on two bytes. Without require to an external database, the description of trash bags content is direcly carried by the tag associated to the trash bag.

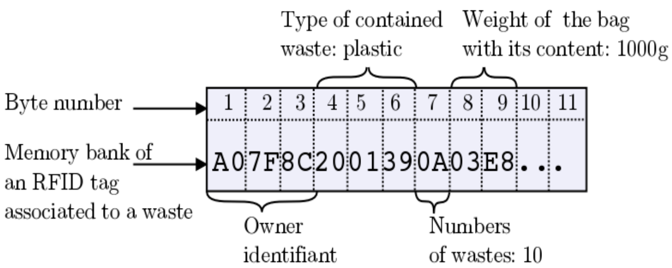

Figure 9. Data memory structuration of a smart trash bag.

The individual smart bin approach presented in Section IV-A assumes that the management system tracks the information of the wastes that are discarded in each container of a selective bin. To this end, the management system updates the analysis report of a container when a smart waste is added in the container. The whole report is stored locally in the memory of a tag associated to the smart trash bags. In the prototype in Figure 6, the analysis report stores the information about the owner of the smart trash bag, the type of the content, the number of wastes, and the weight of the content, using the data representations shown in Figure 9.

We have also developed an application to store the analysis report of the content of a trash bag for the cheaper solution using QR codes technology presented in Section IV-B. In our prototype, the NFC technology provides this second step of the solution: NFC-enabled smartphones can interact in close proximity: in particular, they can read some RFID tags and also emulate the response of some tags. It is in the former functionality that we are interested, as it allows a user to write the required information in a trash bag's tag using only an NFC smartphone.

Figure 10. Writing analysis report operation with a smartphone.

When the bag for a given type is full, the mobile application is used to write the inventory in the RFID tag attached to the trash bag (figure 10). The smartphone uses its NFC reader/writer for this operation. Then the user closes his trash bag of plastic wastes. Now, he uses his smartphones application to write the inventory of the trash bag, in an NFC tag associated to the bag.

D. Collective smart bins

The *collective smart bin* collects the smart trash bags produces by the users. Here, we consider a scenario for the collective smart bins, which can be placed in a condominium of several apartments or in a street. Using the self-describing approach of the smart trash bag, the collective smart bin monitors the flow of wastes, and it detects the alerts: fire, mistake of sorting, detection of undesirable objects. The information about its content is transmitted by an ambient network or local Bluetooth connection during the collection, according to the type of information. As for the individual bin approach for helping the sorting process, it is possible to open a container only when objects of the correct type is brought by a user. The RFID inventories cannot ensure that all the tags have been detected in antenna area of a reader, meaning that missing tags are unnoticed. Considering this limitation, we propose an "incremental" approach, where the global content of the collective container is updated each time a bag is disposed.

The analysis report of the content of a trash bag presented in Section IV-A is used to update content of the collective bin. This approach is based on the self-describing concept of the content of a container. As the same way that the individual container stores knowledge about the wastes, the collective container stores knowledge about the smart trash bags. It is a new way to measure the state of a container without require to the classical use of several sensors. For example, the weight of content, the size, or the type can be measured by using the information store in the tag of each waste of a container, without use one specific type of sensor for a specific property. For example, the total weight of the wastes of a collective container can be estimated by incrementally adding the weigth of each smart trash bag brought to the collective container. The information stored in the tag of the smart trash bag is only needed. This autonomous approach facilitates a large scale deployment of the smart bins.

Figure 11 shows a user in a garbage room. He presents his trash in reading area, where the trash bag's tag is read.

 ISBN: 978-1-61208-282-0

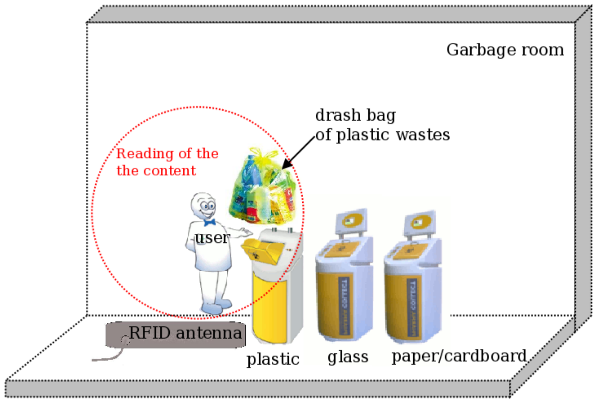

Figure 11. An individual bin using the RFID technology.

The analysis report of the content of the trash bag is transmitted by the reader to the container's controller. The controller can then determine the appropriate action, depending on the bag's content and the local policy. For example, it could reject the bag if it contains an inappropriate item (container remains closed), explaining the cause of rejection to the user (such as "glass is not accepted in this container"). Implementing this policy is a way to avoid that a sorted container is contaminated by undesirable material. For example, it becomes impossible to polluted a container for the plastic wastes with the metal cap of a plastic bottle.

V. Related works

Some other approaches using the RFID technology for waste management systems have already been proposed. In [6], the author discusses about several applications of the RFID in the process of collecting wastes. The identification of each bin associated to a RFID tag is principally mentioned. The storage in a tag associated to each product some information about the end-of-life management process of the product, is also evoked in the paper.

These approaches propose to identify each bin using an identifier stored in a RFID tag associated to the container. In [7], [8], using this identifier, the author proposes to associate in an external database each container with the address of the household owning the container. The volume of wastes estimate the quantity of waste produced by each household. It is not an information based approach but a physical measurement approach using sensor. The estimation of the volume of waste is computed using an image analysis from a picture of the content of the bin (when the lid of the container is opened). The data are transferred using a GPRS connection to an external database.

The idea developped in [9] is also very close to this approach. In [9], a sensor measures the weight of the bin placed on the truck which collects the bins. It differs to our approach which proposes to use a self-describing approach of wastes to compute the weight of a container. At each collection operation, the truck saves the weight of each bin. The RFID tags are used to store an identifier in a external database of the owner of each container. This approach is not autonous, but using a Wifi connection, the external database of waste production is updated for each household. It becomes easy to track the waste production of each household. In [10], the author presents a real deployment of a system using an approach similar to the approach proposed in [9].

The concept developed in [11] rewards consumers for recycling empty packaging. The consumers are identified by a RFID tag associated to their bin. Also based on a weight measurement of their recycling packaging, the consumer can log into his personal account to view how much they have recycled, as well as statistics such as the number of trees saved by their effort. Every month, the consumers are also rewarded financially.

Actually, selective sorting is not the priority of these applications. RFID is used by the container to identify its owner. To ensure the selective sorting, it is track waste at the item level. This is why item level RFID tagging can have an important role to play in the selective sorting, provided that the tag contain information about the components of the waste.

In [12], the presented approach also considers that each product is associated to an RFID tags from the begining of its cycle of life. The information stored in the RFID tags is not used to help the user in the selecting selective process. The authors use the RFID technology at another level of the selective sorting process. The RFID tags associated to each product is used to help the service provider of recycling to decide of the appropriate treatment of a product. In this approach, the data stored in the RFID tags are used to access to the information of products in several databases from a single identifer of each product. This approach of the usability of the RFID technology in the recycling process is not autonomous. A major difficulty is then to shared some conformable information about a product accross several databases, and during all the life cycle of the product.

The main goal developed in [13] is to bring out the environmental impact of RFID used in everyday life. The author discusses RFID for the waste management: a system of discounts and fees to stimulate responsible behavior of users in the selective sorting process, is also discussed. The idea of a bin which collects some information about the wastes is mentioned, although its implementation is not discussed. More generally, in [14], the author predicts an important development of RFID applications in the product recycling chains.

The approach that we propose is innovative in its information processing architecture: the properties are directly attached to physical objects (waste, bags) and data are "moved" and processed along with the physical flow of wastes. Several systems for encoding the waste description are discussed. The most simple way is to encode the component of each waste in plain text. A more advanced approach is described inn [15], where an ontology for waste is used. Class definitions enable fine sorting decision to be taken, based on the waste composition. For example, a bin may accept only items containing at least 90% of plastic. The interest of this method is to select the best bin considering all the components of a waste bring by

 ISBN: 978-1-61208-282-0

a user. For example, all the wastes which contains more than 80% of glass, can be bring to a bin for recycling the glass. This idea could be combined with the approach proposed in this paper to provide a smarter sorting solution.

VI. Conclusion

In this paper, we propose a new solution to enhance waste collection efficiency using the RFID technology. Fully relying on digital information attached to waste items, this approach does not require any sensor, nor external information system support, enabling high scalability and availability. The presented system helps the user in correctly sorting and disposing wastes.

Regarding the waste sorting support, the user is oriented to the correct container to dispose the waste, and is helped in case of errors. Another contribution of this system is to be able to report the content of a bin. This information is useful to waste processing operators, for example to optimize waste collection scheduling, or to set up a special handling when an undesirable product is detected somewhere.

The reported information about the content of each bin is also a way to compute statistics of each type of waste in the recycling process. The smart bins can precisely determine the quantity of each type of waste produces by a household. It should help people to contribute to a more efficient sorting of waste, and reuse valuable materials. By considering the value of wastes produced by each household, it becomes possible to make a retributive incentive system to encourage each user to make the selective sorting of its wastes.

This approach can also help to better plan waste collection and special intervention by operators in case of anormal conditions. The latter feature is based on an ambient communication infrastructure, which we do not describe here. An energy efficient protocol for long life operation such as waste containers is presented in [16].

References

[1] "The EUs approach to waste management," April 2012. [Online]. Available: http://ec.europa.eu/environment/waste/index.htm

[2] H. Boileau and H. Björk, "Comparing household waste treatment policies between two medium size cities: Borås (sweden) and chambéry (france)," in *Proceedings of the 7th World Congress on Recovery, Recycling and Re-integration*, June 2006. [Online]. Available: http://csp.eworlding.com/3r/congress/manu_pdf/420.pdf

[3] "Veolia: Research and Development." [Online]. Available: http://environmentalpassion.com/Research_and_development

[4] "Better Sorting for Better Recycling." [Online]. Available: http://environmentalpassion.com/resource.php?id=2239

[5] Assemblée des Chambres Françaises de Commerce et d'Industrie, "Classification des déchets," November 2011. [Online]. Available: http://www.enviroveille.com/public/documents/nomenclaturedechets.pdf

[6] S. Abdoli, "Rfid application in municipal solid waste management system," in *IJER International Journal of Envionment Research*, vol. 3, no. 3, July 2009, pp. 447–454.

[7] M. Arebey, M. Hannan, H. Basri, R. Begum, and H. Abdullah, "Integrated technologies for solid waste bin monitoring system," in *Environmental Monitoring and Assessment*, vol. 177. Springer Netherlands, 2011, pp. 399–408.

[8] M. Hannan, M. Arebey, H. Basri, and R. Begum, "Rfid application in municipal solid waste management system," *Australian Journal of Basic and Applied Sciences*, vol. 4, no. 10, pp. 5314–5319, October 2010.

[9] B. Chowdhury and M. Chowdhury, "Rfid-based real-time smart waste management system," in *Proceedings of the Australasian Telecommunication Networks and Applications (ATNAC 2007)*, December 2007, pp. 175–180.

[10] J. Wyatt, "Maximizing waste efficiency through the use of rfid," April 2008, Texas Instruments Incorporated. [Online]. Available: http://www.ti.com/rfid/docs/manuals/whtPapers/wp_lf_hdx.pdf

[11] C. Swedberg, "Rfid Helps Reward Consumers for Recycling," in *RFID Journal*, February 2008. [Online]. Available: http://www.rfidjournal.com/article/view/3936

[12] A. Parlikad and D. McFarlane, "Rfid-based product information in end-of-life decision making," in *Control Engineering Practice*, vol. 15, no. 11, 2007, pp. 1348–1363. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0967066106001535

[13] V. Thomas, "Environmental implications of rfid," in *Proceedings of the 2008 IEEE International Symposium on Electronics and the Environment*, ser. ISEE '08. Washington, DC, USA: IEEE Computer Society, 2008, pp. 1–5.

[14] D. C. Wyld, "Taking out the trash (and the recyclables): Rfid and the handling of municipal solid waste," in *International Journal Of software Engineering & Applications (IJSEA)*, vol. 1, no. 1, January 2010, pp. 1–13.

[15] A. Sinha and P. Couderc, "Using owl ontologies for selective waste sorting and recycling." in *OWLED*, ser. CEUR Workshop Proceedings, vol. 849. CEUR-WS.org, 2012.

[16] N. Mitton, D. Simplot-Ryl, M.-E. Voge, and L. Zhang, "Energy efficient k-anycast routing in multi-sink wireless networks with guaranteed delivery," in *Proceedings of the11th International Conference on Ad-Hoc Networks and Wireless*, ser. ADHOC-NOW'12, Belgrade, Serbia, July 2012, pp. 385–398.

Co-Production of Health in Smart Cities: The M3 Case Study

Vicini Sauro, Bellini Sara and Sanna Alberto
City of the Future Living Lab
Fondazione Centro San Raffaele
Milan, Italy
vicini.sauro@hsr.it

***Abstract* — Personalized interventions that empower users through pertinent and reliable information - alongside ubiquitous and user-friendly services, interfaces and products - can provide users with the opportunity to adopt healthy lifestyle choices, which improve quality of life and help prevent a vast number of chronic diseases. This paper would like to present the case of the Mobile Medical Monitoring (M3) project as representative of the work carried out by the eServices for Life and Health research unit alongside the City of the Future Living Lab; this project was based on an eService design approach of deploying innovative ICT (Information and Communication Technology) and multi-device based services. The focus of this paper is therefore to explore the Engineering Awareness™ approach alongside the co-creation living lab methodology.**

Keywords: Co-production; ICT; Living Lab; eService design; Co-creation Living Lab process.

I. Introduction

The World Health Organization (WHO) estimates that chronic, non-communicable diseases (NCDs) are the leading cause of morbidity, disability and mortality across all countries of the globe, and that these are all related to an individual's lifestyle choices. As a result, there is an impellent need for medicine and the delivery of healthcare services to play a much more proactive role in an individual's life and to develop strategies that address the individual in a human-centric, non-intrusive and eco-sustainable manner in order to trigger long-lasting and healthier lifestyle-choices and behavior patterns.

This paper will initially address briefly those different strategies identified by the e-Services for Life and Health research department of San Raffaele Hospital (FCSR) which should be adopted in order to improve the way in which healthcare services actively participate in an individual's life; further on, the paper will briefly present the Mobile Medical Monitoring (M3) Case Study and how this service, embodying those strategies, had an effect on a study group.

II. Strategies for Improving the Delivery of Healthcare Services

The strategies developed by the e-Services for Life and Health unit can be summarized as follows (and will be described in the upcoming paragraphs): a revisited and ICT-enabled and smart clinical assessment process; prevention through personalized information and education, together with a more active role on the part of healthcare professionals; the adoption of a co-production approach.

A. *Transform prescriptions into an experience*

In order to improve their efficacy in disease prevention as well as disease control and management, medicine and health delivery services need to play a more proactive role in an individual's life. To be able to understand the importance of adopting healthy lifestyle choices and behavior patterns in the prevention of disease or how to best manage a diagnosed condition and prevent it from becoming chronic, an individual must be informed and educated via a network of trustworthy healthcare professionals. The information provided by those figures of reference should be personalized and contextualized – reflecting an individual's real everyday needs and objectives – to avoid being viewed as impositions but rather as motivational triggers.

In order to provide such rich and targeted information, a 360° profile of the individual must exist, a profile which matches both medical data as well as lifestyle and personal data. In other words, a drug prescription should no longer be a list of medicines, doses and times of day in which they should be administered; rather, it should be a lifestyle prescription, composed of comprehensible, practical and actionable advice; it should also include on-demand continuous guidance that the individual can relate to at all times in a typical day and throughout his/her life. The doctor-patient relationship is thereby raised to a higher level of mutual collaboration, thus forming a Health Personal Guidance System (Health PGS).

At all levels of society, individuals may not necessarily have the proper skills to make informed choices or the appropriate culture to understand risks. At the same time, they may not have the opportunity to elaborate compatible alternatives (should those alternatives be offered to them). It is for this reason that personalized, contextualized and pertinent information and education are key in promoting responsible and conscientious lifestyle choices. Indeed, there are many examples and discussions in literature that address the concept that the greater degree to which interventions are personalized and involve highly-skilled medical experts the higher their success rate when compared to the impersonal interventions of mass media communication campaigns.

B. *ICT as a healthier ecosystem enabler*

Such a detailed, individual profile will present healthcare professionals with an unprecedented amount of an personal

 ISBN: 978-1-61208-282-0

data, both medical and lifestyle-related. From a knowledge management perspective, a radical change in the structure of the Electronic Healthcare Record (EHR) systems will have to occur, evolving from the present semi-static paradigm into a completely different and much broader one, that eServices for Life and Health unit likes to call the Personal Health Record (PHR). The PHR must give structure to the rapidly growing, vast amount of dynamic patient data spread across a multiplicity of specialties and gained via a widespread set of actuators (including existing databases, the individual himself/herself, remote devices, embedded technologies and sensors, healthcare smart cards and so on), thus demanding exceptional levels of data storage, data protection, data visualization, decision support and analytical tools that can be enabled only by a total redesign of ICT platforms.

ICT platforms must therefore expand and embrace a multitude of fields of activities and meaningful data from industry, education, community participation, technical infrastructure and various soft factors [1] in order to produce an ICT network able "to transform life and work … in significant and fundamental, rather than incremental, ways" [2], thus producing a Smart City which promotes and supports the prescription experience.

C. A co-production approach

In a traditional sense, co-production in healthcare refers to the contribution of service-users to the provision of services [3]. It is an approach which challenges the usual relationship between professionals and service-users since it stimulates the latter to be considered experts in their own circumstances and therefore capable of making decisions and having control as responsible citizens [4]. Co-production also implies a change in the role of healthcare professionals, from fixers of problems to facilitators who find solutions by working with their clients [5].

The e-Services for Life and Health research unit and the City of the Future Living Lab have developed a model and a methodology that embody the essence of the co-production approach, bringing it to a new level where the end-user is truly an active participant in a healthcare service. The following two sections will address both these developments.

III. ENGINEERING AWARENESS™

Engineering Awareness™ (Fig. 1) is a unique service design model that synchronizes emotions (a trigger to an individual's psychological reaction in context with his/her preferences) and relations (a trigger for a social interaction with other individuals physically present or not, and/or with a proximity or remote environment in context with his/her preferences) with regard to functions (an individual's practical need addressed by the service) delivered.

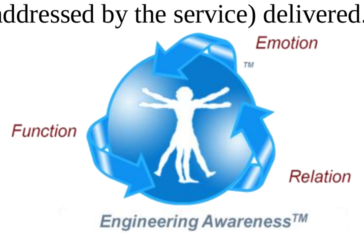

Figure 1. Engineering Awareness™.

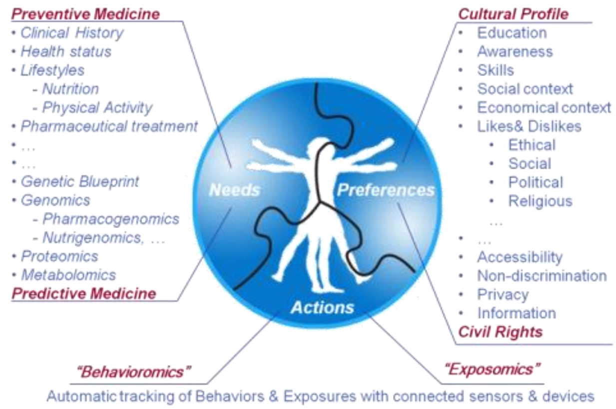

Figure 2. Engineering Awareness™, a model on health and lifestyles.

Designing for an individual's awareness and behavioral change is the primary ethical objective of any personalized service developed within the eServices for Life and Health unit. The mission of this research unit is not to manipulate individuals (i.e., making them do a supposedly "right thing/healthy thing" decided on their behalf by a knowledgeable third party) but to provide them with an unbiased understanding of the impact that a given decision/action implies. Each individual is characterized by his/her own digital profile, a complex, dynamic and progressive repository of personal data, information and events which is split into three parts as illustrated in Fig. 2:

- needs, i.e., the medical part of the profile: the genetic blueprint and the meaningful biochemical/physiological parameters of an individual that are considered relevant for a statistical health risk assessment at the level of state-of-the-art knowledge in primary/secondary preventive medicine and predictive medicine;
- preferences, i.e., the "personal preferences" section of the profile: the unique cultural resources of an individual, including his/her likes and dislikes and ethical beliefs;
- actions, i.e., "the health-related actions" part of the individual's profile: the unique (and constantly evolving) series of meaningful, health-related actions performed by an individual ("Behavioromics") and exposures to environmental factors ("Exposomics") in his/her daily life.

IV. THE CO-CREATION LIVING LAB METHODOLOGY

The San Raffaele City of the Future Living Lab is an ecosystem within an area of 300,000 m^2 that can be described as a tertiary urban area (or a compact urban district) where all typical, daily operations are concentrated within a reduced space. The way it has been designed allows its research team to access, understand, study and measure the interactions among an estimated 27,000+ community of City of the Future daily-users (20,000+ a day turn-over of inpatients, outpatients and visitors of all ages and needs; 5000+ on-site employees, researchers, etc.; and 1700+ students).

It is both a virtual as well as real research environment and community, managed and organized by the eServices for Life and Health research unit. The Living Lab follows the conceptual framework presented by ESoCE-Net in which user-driven and open innovation is fully integrated within the co-creation process of new services, products and societal infrastructures [6]. As of 2012, the City of the Future Living Lab has been awarded membership of the Enoll (European Network of Living Labs) network.

Such a unique environment has been the field of international ICT research projects in 5th, 6th and 7th European Commission Framework R&D Programs and Italian/Lombardy Region R&D Programs since 2000, nurturing intense, cross-disciplinary collaborations among medical and healthcare professionals, designers, engineers, scientists, policy makers and entrepreneurs across a number of well-being, life and health-related fields.

Living Labs are innovation environments that focus on user communities embedded within "real life" situations and environments. The fundamental concept at the base of a Living Lab is to gain direct and unfiltered access to users' ideas, experiences and knowledge, based on their daily needs and desires of feeling supported by products, services or applications. The Living Lab methodology ideated and put into practice by the City of the Future Living Lab is based on a revisited version of the traditional Living Lab methodology and is centered around a co-creation approach. Indeed, end users as well as stakeholders (including City of the Future Living Lab designers, information technology and mechanical engineers, project managers and ethnographers, as well as pediatricians, psychologists, dieticians, physiotherapists, sociologist, nutritionists, teachers, marketers and so on) are actively involved throughout project ideation, exploration, implementation and experimentation. Such an approach was chosen because the City of the Future Living Lab firmly believes that users and stakeholders should influence the design process so that what comes out of it is a solution that can respond effectively to their needs and fit into their everyday lives. Insights are gathered directly from the users in order to define and implement realistic, useful, desirable and effective artifacts.

The Co-Creation process ideated and developed by the City of the Future Living Lab is based on four concurrent phases (Fig. 3): Co-design; Implementation; Experimentation; Evaluation. Since this approach is an iterative and reflective one, a starting point remains undefined, and the Living Lab process can be commenced at any stage of the design activity.

V. M3 CASE STUDY

Mobile Medical Monitoring (M3) is project funded by the Italian Region of Lombardy. It consists of a wearable patch, shown in Fig. 4 (composed of a durable part to which standard electrodes can be attached), a smartphone and tablet app and web portal. It is a service where users (both professional athletes as well as average individuals)

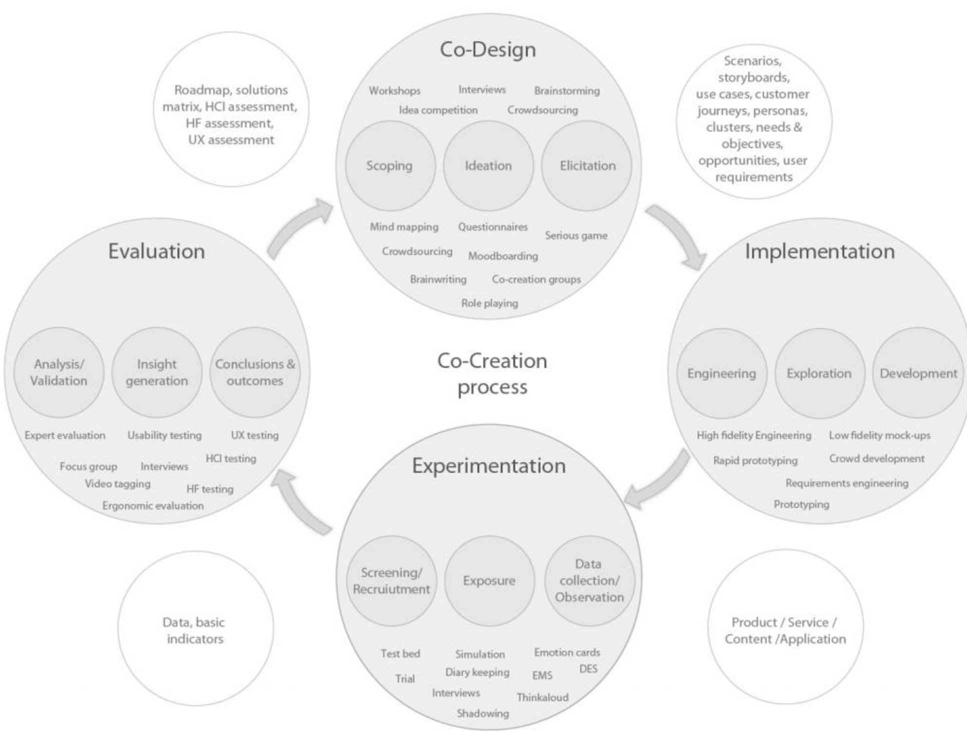

Figure 3. The Co-Creation Living Lab methodology adopted by the City of the Future Living Lab

 ISBN: 978-1-61208-282-0

can monitor different biological parameters (e.g., heart rate, breathing and metabolic equivalents) and share this data, along with other information, with their trainers, doctors, nutritionists and so on, in order to receive from them personalized help via both the app and the web portal. This service is integrated with individuals' PHR. The M3 information platform is also complemented by a non-clinical, educational and motivational platform whose aim is to promote active lifestyles for the general public.

Figure 4. The M3's Patch and Smartphone applications

The M3 project is currently in its evaluation phase. The project started off with a very strong and highly-technological objective: to create a working platform of an ICT-enabled and Smart service for healthcare prevention and education able to be integrated with both physiological as well as behavioral data. Thus, the co-design phase consisted of the participation in a focus group of expert users (including nutritionists, cardiologists, biomedical engineers and professional athletes) alongside a team of City of the Future researchers (including engineers and designers). Throughout this activity, the different actors were guided through a phase of analysis (with questions like "who could the service's end-user be", "what are the user requirements of this user", "in what context could the service be used on a day-to-day basis", "what other similar products and services already exist" and so on) as well as through a phase of brainstorming.

The insights gathered from the co-design phase (and which include the Engineering Awareness^{TM} Model) were used as base for the implementation phase, where ideas and user and service requirements were translated by the City of the Future's tech team into a series of rough prototypes for the smart patch. In order to evaluate both the comfort of the patch as well as the correct flow of data from the patch through the smart device application to the platform (Fig. 5), these criteria were tested by volunteers recruited by the City of the Future Living Lab, including both sports enthusiasts as well as individuals uninterested in physical activity.

Figure 5. Moments during the M3's Implementation phase

Following the implementation phase, a more refined prototype of the service was administered to a new set of volunteers. For a period of three consecutive days, ten individuals were divided into two groups: the first who was asked to wear the patch, use the smart device application and the web platform; the second was asked to wear only the patch and not access the M3 app or portal. The reason for this was to explore the impact that viewing one's physiological data or receiving communication on behalf of a medical professional could have on the service.

Throughout the experiment, all participants were asked to keep notes of their day-to-day experiences, and, following this timeframe, they were interviewed by a researcher at the City of the Future Living Lab and asked to answer a questionnaire. Qualitative data regarding the usability and overall user experience of the entire service was then collected.

During the evaluation phase, what emerged from the questionnaires (composed of three sets of nine statements for patch, app and portal, to which each participant had to select to what extent they identified with them by selecting a number from 0-5, alongside two open-ended questions for each element of the service where participants could freely write down any comment they wanted); and interviews are a set of insights, which will be further analyzed during the evaluation phase by a set of usability experts.

For the majority of participants, the patch was described as easy to position, to wear and to charge (it received a vote above 3/5 for 9 out of 10 participants). It was also deemed easy to read and to use, though scores were slightly lower, suggesting that the patch's interface needs improvement (it received a vote above 3/5 for 8 out of 10 participants). The patch was also described as having a strong appeal since participants found it innovative, original, attractive and inviting (it received a vote above 3/5 for 9 out of 10 participants).

Nevertheless, for six out of ten participants, there were some wearability issues regarding the electrodes since, after awhile, they were described as irritating to the skin (especially for women) or beginning to peel off (especially during strenuous, sweaty physical activity) or impeding movement during physical activity.

Though all participants got used to wearing the patch (eventually, even those who wore it during physical exercise), it was much harder for them to remember to bring along the device assigned to them and upon which the M3 app was downloaded (especially for those with a tablet). As of today, the patch requires the user to have a device through which to send the collected data to the platform since it can store only a certain amount at a time.

Copyright (c) IARIA, 2013. ISBN: 978-1-61208-282-0

This fact suggests that the memory of the patch would benefit from being expanded or for there to be a smaller device to be integrated into the system for the storage and passing on of data to the platform.

Instead, the app and portal were described as less usable since the language adopted was not always clear, navigation was not always intuitive and the data visualized in the form of charts was not always easy to decode and understand, and users therefore found it difficult to relate to.

For those who could access the app and portal, the service was described as being able to trigger a new awareness or consciousness of one's state of health (receiving a vote above 3/5 for five out of five participants). Individuals felt that seeing their data made them more curious about their state of health and how to improve it and preserve it throughout the day. Some said that they were going to speak to their doctors about what they had learned, wanting to understand how they could improve their state of health. One person said that participating in the experiment made her want to take up a sports activity or at least be more physically active during the day (using the stairs or walking to the closest metro station rather than taking the bus), whilst another participant who, instead, was a sports enthusiast said it made her want to perform better during training. A small minority felt that wearing the patch and having a service that stores data made them feel more looked after and secure, whilst another small minority felt that wearing the patch almost made them feel ill or different.

All participants who had access to the patch, app and portal stated that the device's pairing process with the app and the visualization of data on the portal could be improved and made more intuitive. They also suggested enriching the portal in the following ways: direct feedback from doctor or sport trainer or nutritionist; ways of tagging data so that non-biological info, such as lifestyle activities or emotional states, could be associated with it; introduce ways of cross-referencing data in a personalized manner in order to understand the whole picture better, thus making it more meaningful; possible setting ranges so that, during physical activity, the patch would vibrate or produce a sound to indicate that the individual has exceeded the desired parameters; a social network where people who like the same sports can organize training or people who work together can meet up for lunch and have a walk.

The feedback collected and the insights which are being analyzed show how important and valuable it is to involve the end-user throughout a service's innovation process. This feedback highlights improvements and modifications that can help deploy a healthcare service that truly understands and meets the needs of the end-user. Through meaningful information and education, a drug prescription can turn into an experience able to motivate people to live a healthier, more conscientious life.

VI. Conclusions

The overall user experience of the M3 service described in this paper by those who participated in the experimentation of the patch, the M3 app and portal was positive; more importantly, however, it has emphasized the service's high potential for improvement via a co-operative and participatory approach. The patch alone generated little appeal beyond that of the attraction to its novelty, whilst the app and portal generated more involvement, showing that a service which provides added value through meaningful information can raise awareness and conscientiousness of healthy lifestyle choices and disease prevention.

Throughout the innovation process of a smart and ICT-enabled healthcare service, the M3 project is a practical representation of the methodology adopted by the City of the Future Living, taking the co-production of healthcare services to a new level of active participation and contribution on behalf of the end user. Having a living lab through which to explore and develop a service allows researchers to have direct, unfiltered and continuous access to a vast number of users which promotes participation and produces user insights. It is just these insights that can mould a service's ability to permeate successfully everyday life because it is able to respond to real user needs as embodied by the Engineering Awareness™ model.

References

[1] R. Giffinger, C. Fertner, H. Kramar, P. Kalasek, N. Pichler-Milanovic, and E. Meijers, "Smart cities – ranking of European medium-sized cities", Centre of Regional Science, Vienna, 2007.

[2] California Institute for Smart Communities, "Ten steps to becoming a smart community", California, 2001.

[3] A. Realpe, and L. M. Wallace, "What is co-production?," The Health Foundation, London, 2010.

[4] D. Boyle, S. Clarke, S. and Burns, "Aspects of co-production: the implications for work, health and volunteering", New Economics Foundation. London, 2006.

[5] C. Needham, and S. Carr, "SCIE Research briefing 31: co-production: an emerging evidence base for adult social care transformation," Social Care Institute for Excellence. London, 2009.

[6] R. Santoro, and M. Conte, "Living Labs in open innovation functional regions", ESoCE-NET White Paper, Rome, 2010.

 ISBN: 978-1-61208-282-0

Advanced Street Lighting Control through Neural Network Ensembling

Stefano Pizzuti, Fabio Moretti, Mauro Annunziato
ENEA (Energy New technology and Environment Agency)
Rome, Italy
stefano.pizzuti@enea.it
fabio.moretti@enea.it
mauro.annunziato@enea.it

Stefano Panzieri
Università Roma Tre
DIA (Department of Informatics and Automation)
Rome, Italy
panzieri@dia.uniroma3.it

***Abstract*—In this work, we propose an innovative street lighting energy management system in order to reduce energy consumption. The main goal is to provide 'energy on demand' such that energy, in this case light, is provided only when needed. In order to achieve this purpose it is critical to have a reliable demand model, which in the case of street lighting turns out to be a traffic flow rate forecasting model. Several methods has been compared in order to find out one hour prediction model. In our case studies, Artificial Neural Networks performed best results. Moreover, several control strategies have been tested and the one which gave the best energy savings is the adaptive one we carried out. Experimentation has been carried out on two different case studies. In particular we focused our experimentation on public street of a small and a medium sized cities. Our studies show that with the proposed approach it is possible to save up to 50% of energy compared to no regulation systems**

Keywords-Lighting Efficiency; Energy Management Systems; Adaptive Control; Neural-Network models

I. INTRODUCTION

Since the first international recommendations for the lighting of roads [1], power consumption and environmental aspects have become more and more important and at the same time, the improved performance of luminaires and lamps, and especially the introduction of electronic control gears, has made it possible to introduce adaptive lighting for motorized roads and pedestrians areas.

A structured model has been developed for the selection of the appropriate lighting classes [2] (M, C, or P), based on the luminance concept, taking into account the different parameters relevant for the given visual tasks. Applying for example time dependent variables like traffic volume or weather conditions, the model offers the possibility to use adaptive lighting systems with remarkable energy consumption savings and therefore high financial benefits for those municipalities [3] where street lighting is a high percentage of the electrical bill.

Today, lighting control approaches ranges from simple on/off to regulation systems.

On/off systems include timers, twilight and astronomical clocks. The first one is a static system which turns on and off street lights always according to fixed times. The second one has light-sensitive photocells to turn them on at dusk and off at dawn [5]. The third ones are GPS based street light controllers which operate the on/off of the street light according to the location features (longitude, latitude, sunrise, sunset times).

Regulations systems are based on dimmable LED or high pressure sodium vapor lights [4] and allow to schedule lights on or off and set dimming levels of individual or groups of lights.

All these systems have one common feature: they do not care about the real on-line demand and this is a source of high inefficiency.

Thus, in order to overcome the main lack of the current regulation systems, it has recently started the new Intelligent Street Lighting (ISL) approach which looks very promising [5]-[6]. Therefore, here we propose an ISL approach (Smart Adaptive Control) based on the concept of 'energy on demand', whose goal is to dynamically set the light intensity as function of the foreseen demand, namely the traffic flow rate 1 hour forecast.

Thus, in such context the demand model has a critical role and its accuracy strongly affects the performance of the regulation system.

In the last decade, one of the most widely used method in order to solve modeling problems is that of Artificial Neural Networks (ANN) [7]-[8]. In particular, traffic flow forecasting issue has been tackled through ANN since the nineties [9]-[19]. As example, among the most recent work [19] focuses on traffic flow forecasting approach based on Particle Swarm Optimization (PSO) with Wavelet Network Model (WNM). Pamula [16] reviews neural networks applications in urban traffic management systems and presents a method of traffic flow prediction based on neural networks. Bucur et al. [17] proposes the use of a self-adaptive fuzzy neural network for traffic prediction suggesting an architecture which tracks probability distribution drifts due to weather conditions, season, or other factors.

All the mentioned applications have one feature in common: they use one single global model in order to perform the prediction. Our approach is to use not only one model but an ensemble of models. In Section II an overview of modeling methods used is given, in particular statistical and Artificial Neural Network based models and their combination trough ensembling. In Section III we show results obtained on two case studies and then in Section IV we discuss future works.

II. MODELING METHODS

In this section, we shortly describe the modeling and control techniques we compared in the experimentation.

A. Statistical Modeling

One the simplest and most widely used model is to build an average weekly distribution of the traffic flow rate sampled hourly. Thus, from the data we compute for each day the average traffic flow rate hour by hour in such a way that we get an average distribution made of 24X7=168 points.

B. Artificial Neural Networks

Artificial Neural Networks (ANN) are computational models which try to simulate some properties of biological neural networks in order to solve complex modeling problems of non-linear systems. An ANN is an interconnected group of artificial neurons (called also nodes) that uses a mathematical or computational model for information processing based on a connectionistic approach to computation. In more practical terms ANN are non-linear data modeling or decision making tools which can be used to model complex relationships between inputs and outputs or to find patterns in data. ANN are referred also as black-box or data-driven models and they are mainly used when analytical or transparent models cannot be applied. Building such models needs several stages as input analysis and training through algorithms which minimize the error between the real values to be modeled and the ANN output. ANN demonstrated their effectiveness in modeling many real-world applications.

Once we model an ANN model, we must take into account three basic components. First, the synapses of the biological neuron are modeled as weights. Let us remember that the synapse of the biological neuron is the one which interconnects the neural network and gives the strength of the connection. For an artificial neuron, the weight is a number, and represents the synapse. A negative weight reflects an inhibitory connection, while positive values designate excitatory connections. The following components of the model represent the actual activity of the neuron cell. All inputs are summed altogether and modified by the weights. This activity is referred as a linear combination. Finally, an activation function controls the amplitude of the output. Mathematically, this process is described in Figure 1. From this model the activity of the neuron can be shown to be:

$$y=f_a(\Sigma w_i x_i - \theta) \tag{1}$$

where θ is a threshold called BIAS (Basic Input Activation System) which identifies the sensitivity of the neuron to respond to the external inputs. The most common function used to model f_a are the hyperbolic tangent, the sigmoid and the linear function.

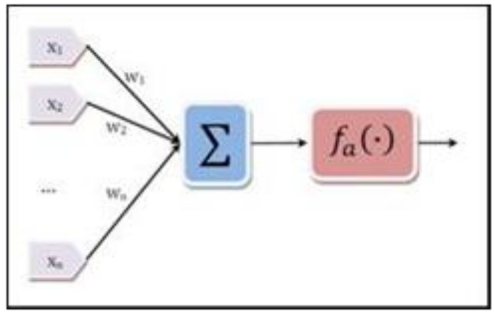

Figure 1. Artificial Neuron Model

Therefore each unit performs a relatively simple job: receive input from neighbors or external sources and use this to compute an output signal which is propagated to other units. Apart from this processing, a second task is the adjustment of the weights. The system is inherently parallel in the sense that many units can carry out their computations at the same time. Within neural systems it is useful to distinguish three types of units: input units which receive data from outside the neural network, output units which send data out of the neural network, and hidden units whose input and output signals remain within the network.

The way units are connected defines the network topology or architecture. In the past years, many of them have been studied and the most widely used and is the feed-forward one. In this network structure, neurons are grouped into layers. There are at least two layers, the input and the output, which gather the corresponding input and output variables. This basic structure is also known as perceptron [20].

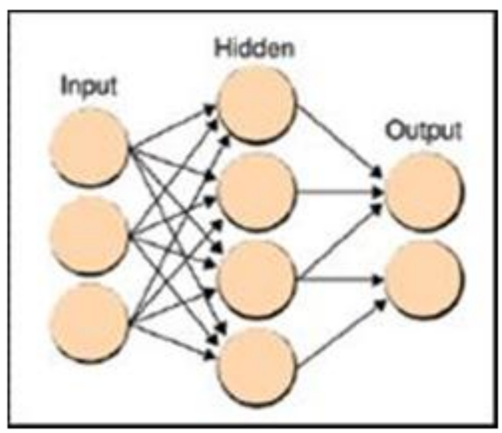

Figure 2. Feed-forward neural network topology

Moreover, in order to let the model cope with non-linear problems, it is possible to add one or more intermediate layers, known as hidden layers. These models are also known as multi-layer perceptrons (MLP) [21].

The flow of data from input to output units is strictly in one direction (forward). The data processing can extend over

 ISBN: 978-1-61208-282-0

multiple (layers of) units, but no feedback connections are present, that is, connections extending from outputs of units to inputs of units in the same layer or previous layers.

C. Ensembling

The term ‘ensemble’ describes a group of learning machines that work together on the same task, in the case of ANN they are trained on some data, run together and their outputs are combined as a single one. The goal is obtain better predictive performance than could be obtained from any of the constituent models.

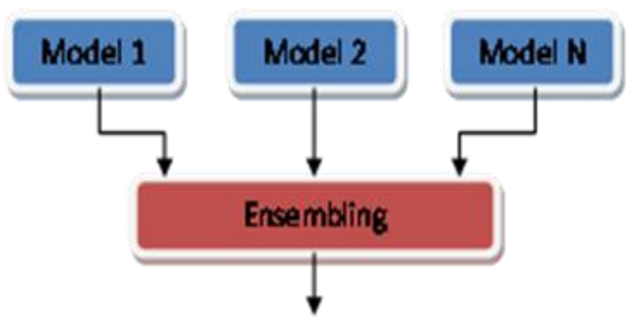

Figure 3. Ensembling

In the last years several ensembling methods have been carried out [22],[23],[24]. The first one, also known as Basic Ensemble Method (BEM), is the simplest way to combine M neural networks as an arithmetic mean of their outputs yi. This method can improve the global performance [25],[26] although it does not takes into account that some models can be more accurate than others. This method has the advantage to be very easy to apply.
A direct BEM extension is the Generalised Ensemble Method (GEM) [25],[26] in which the outputs of the single models are combined in a weighted average where the weights have to be properly set, sometimes after an expensive tuning process.
Other methods are Bootstrap AGGregatING (BAGGING) [27] and Adaboost [28],[29].

III. EXPERIMENTATIONS

In this section, we test and compare the methods presented in the previous sections. We used two test cases: one has concerned Terni and the second regards S.Giovanni in Persiceto.
In the first one, we focused on three different urban streets of Terni (Table I). The data set is made of 3 months (13 weeks) of measurement corresponding to 2184 hourly samples. The data set has been partitioned into training/testing and validation made respectively of 10 and 3 weeks each.

TABLE I. STREET FEATURES

	Maximum traffic flow rate
Street 1	600
Street 2	800
Street 3	950

A. Modeling

The basic idea is to set the power level of the following hour as function of the ANN ensemble forecast.

$$P_{t+1} = f(\phi_{t+1}) \tag{2}$$

where P_{t+1} is the power level normalized in [0,1] to be set for the next hour, ϕ_{t+1} is the traffic flow rate neural forecast which is

$$\phi_{t+1} = anne(\phi_t, \phi_{t-1}, \dots, \phi_{t-n}) \tag{3}$$

where *anne* is the ANN ensemble result, ϕ_{t-i} is the measured traffic flow rate at time *t-i*.
For Street lighting applications function *f* in (2) can be shaped in different ways, among these we applied a linear profile although international standards [2] suggest a non-linear one that we will apply in future work.

$$\begin{aligned} &\text{If } \phi_k < 0.25 \text{ then } f = 0.5 \\ &\text{If } \phi_k > 0.5 \text{ then } f = 1 \\ &\text{Else } f = 2\phi_k \end{aligned} \tag{4}$$

where ϕ_k is the predicted traffic flow rate at time *k* (3) normalized in [0,1].
The ANN are feed-forward MLP with 10 hidden neurons and one output (the one hour flow forecast) with sigmoid as activation function for all the neurons. The number of inputs is the same of the dynamics window length (3) and it has been chosen with a preliminary analysis by calculating the validation prediction error, after the ensembling stage, for different number of hourly samples (Table II). Since we obtained the minimum prediction error with a time window of eight hours, we chose the same number of inputs for the ANN, representing the length of time history window. So each input contains the traffic flow of one of eight hours of the time window.
Training has been performed through the Back-Propagation algorithm with adaptive learning rate and momentum stopping after 108 iterations and a ‘save best’ strategy to avoid overfitting. The reported results are averaged over 10 different runs (with standard deviation in brackets) and the ensemble is therefore made by the same 10 models.
The reported errors are measured as:

$$e = |x-y|/(M-m) \tag{5}$$

Where x is the real value to be predicted, y is the output model, M is the real maximum value and m is the minimum.

TABLE II. WINDOW HISTORY LENGTH (HOURS) SELECTION

Number of Samples	Street 1	Street 2	Street 3
3	5.72%	6.88%	5.81%
5	3.9%	5.07%	3.99%
8	**3.29%**	**3.43%**	**3.02%**
10	3.54%	4.12%	3.74%

At last, Table III shows the comparison of the models considered in this work in terms of prediction accuracy over the validation set. Figure 4 shows a graphical comparison. We compared real hourly traffic flow rate with prediction provided from statistical and neural network ensemble models. Ensemble models outperforms statistical in all cases.

TABLE III. MODEL COMPARISON

	Statistic	ANN	ANN Ensembling
Street 1	5.90%	3.74% (±0.10%)	3.29%
Street 2	5.56%	3.48% (±0.09%)	3.02%
Street 3	7.14%	4.00% (±0.10%)	3.43%
Average	6.20%	3.74% (±0.10%)	**3.25%**

From this analysis it is clear that in general the ensembling approach outperforms the statistical approach providing a remarkable improvement in prediction accuracy. Such level of precision is very important when dealing with applications like traffic and lighting control where the higher the model accuracy is the more effective the control system is.

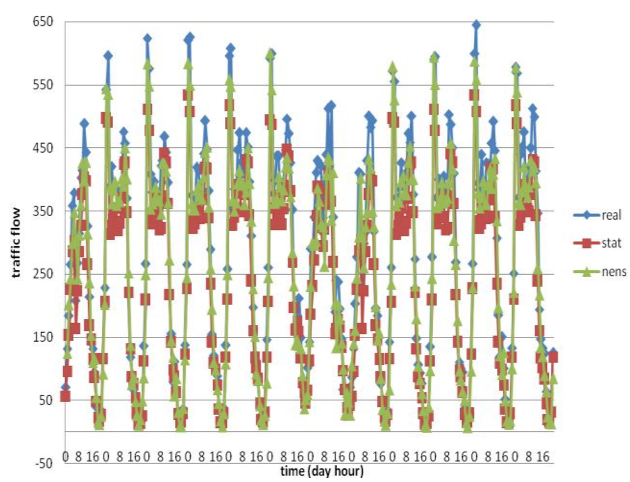

Figure 4. Models comparison

From this graph it is clear that the ANN ensemble model performs much better than the statistical model because, when out of normal conditions the ANN ensembling takes into account the real traffic dynamics (3).

B. Control

In this section, we compare the results of the Static Control (StaC) and the Smart Adaptive Control (SmAC) introduced in Section III.

In the experimentation we calculated the energy saving of the two methods with respect to the no-regulation strategy, namely when lights are always on at 100% of their power for the whole night.

The light on demand control assumes dimmable lights (SAP or LED), on the streets we carried out this study there were no such lamps and data about the real consumptions were not available, therefore the experimentation has been carried out off-line by calculating the potential energy consumptions in the following way. It has been assumed the maximum hourly nominal power consumption to be one, then the following quantities have been calculated :

$$C_{100} = \sum x_1^{\,i}\ ,\ x_1 \in \{0\ ,\ 1\} \qquad (6)$$

Where x_1^i is the hourly power level for the i^{th} sample according to the no control strategy (night power level always at 100%) and therefore C_{100} is its overall consumption.

$$C_{StaC} = \sum x_2^{\,i}\ ,\ x_2 \in \{0\ ,\ 0.5\ ,\ 1\} \qquad (7)$$

Where x_2^i is the hourly power level for the i^{th} sample according to the static control (StaC) strategy (Fig. 4) and therefore C_{StaC} is its overall consumption.

$$C_{SmAC} = \sum x_3^{\,i}\ ,\ x_3 \in [0\ ,\ 1] \qquad (8)$$

Where x_3^i is the hourly power level for the i^{th} sample (4) according to the smart adaptive control (SmAC) strategy (Fig. 5) and therefore C_{SmAC} is its overall consumption.

These quantities have been calculated over three months of actual traffic flow rates obtained by on street coil sensors. Thus, we computed the consumption saving of the StaC and SmAC strategies with respect to the no control approach in the following way :

$$S_{StaC} = 1 - C_{StaC} / C_{100} \qquad (9)$$
$$S_{SmAC} = 1 - C_{SmAC} / C_{100} \qquad (10)$$

In Table IV, we report these values for the three considered streets.

 ISBN: 978-1-61208-282-0

TABLE IV. CONTROL STRATEGY COMPARISON: ENERGY SAVING

	StaC	SmAC
Street 1	25%	44.5%
Street 2	25%	47%
Street 3	25%	37.5%
Average	**25%**	**43%**

Results show that it is possible to save on average 43% of energy, meaning that lamps will work at 57% of their nominal power having as inferior limit 50% (4) and Fig. 5 in order to avoid periods during normal operation with almost no light due to light output drop.

From these results it is clear that the SmAC approach provides a remarkable improvement in terms of energy saving (43% on average) in particular on streets with medium-low traffic flow rate.
Moreover, in Figure 5 it is shown an example of how the two strategies work, where on the Y axis we report the normalized traffic flow rate values and the normalized hourly power consumptions of the different strategies. From Figure 5 it is possible to see that the SmAC strategy is capable to follow the real demand (traffic flow rate) achieving the ‘energy on demand’ concept. In particular, it is interesting to point out that SmAC improves not only energy efficiency (orange dotted area) but also safety (yellow dashed area) because it provides light when actually needed.

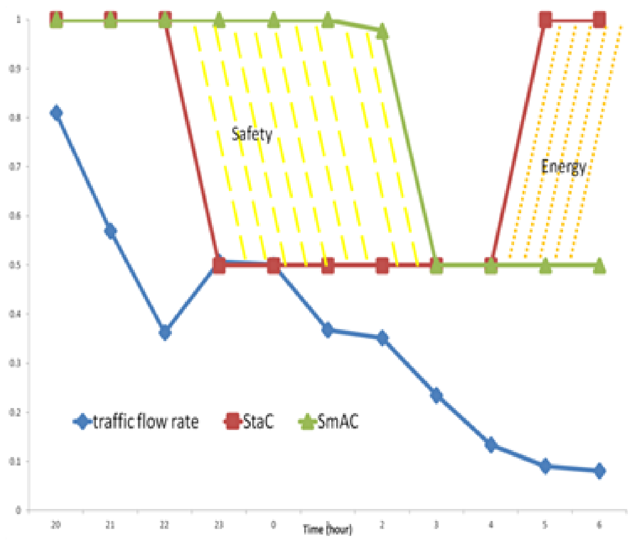

Figure 5. Control strategy comparison

Tests performed on S.Giovanni in Persiceto are based on a dataset of 123 days, sampled hourly, for a total of 2952 hours. Once again we compared different forecasting system:

- *Actual hour*: next traffic flow prediction based on previous hour traffic flow
- *Previous week*: forecast based on the same hour and the same week day of the previous week
- *Statistic model*: averaged hourly profile
- *Neural Ensembling*: neural network ensembling based model

TABEL V. COMPARISON OF FORECASTING MODELS ERRORS

	Actual Hour.	Previous week	Statistic model	Neural Ensembling
Error	8.77%	7%	5.53%	4.39%

Results show that also in this case Neural Ensemble outperforms other methods.
Then we compared three different control described above: constant, static and adaptive. As shown in Fig. 6 constant control does not take in account the traffic flow, static control does not overcome the variability of traffic flow meanwhile adaptive control provide energy to lighting spot proportional to traffic flow.

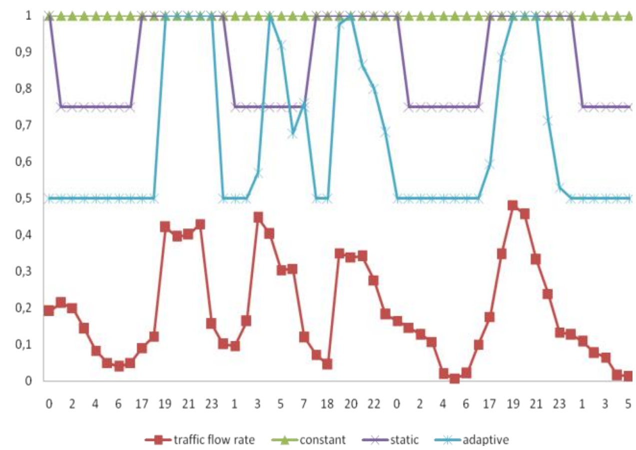

Figure 6. Comparison of control strategies

TABLE VI. CONTROL STRATEGY COMPARISON (ENERGY SAVING)

Static Control	Adaptive Control
-12%	-34%

Energy saving show in Table VI is a theoretical evaluation respect of constant control.

IV. CONCLUSIONS AND FUTURE WORKS

In this work, we proposed a new approach for adaptive street lighting control based on the ‘energy on demand’ idea. In order to achieve this goal it is critical to have a reliable demand model, which in the case of street lighting turns out to be a traffic flow rate forecasting model.
Thus, we showed a modeling approach based on Artificial Neural Networks Ensembling in order to provide a one hour forecast of urban traffic flow rates. Experimentation has been carried out on three different classes of real streets and

results showed that the proposed approach clearly outperforms the statistical methods (6% prediction error) achieving a 3% prediction error. The reason for that is that the neural ensembling model is capable to provide more reliable estimations when out of standard conditions because it considers the real traffic dynamics.

Moreover, the proposed adaptive control strategy has been tested and compared to a traditional regulation system on the same streets. Results showed that the adaptive control provides, on average, energy savings almost doubled (43% vs 25%).

Future work will firstly focus on dimming profiles according to international standards, then further modeling improvements (using more sophisticated ensembling methods as well as trying to develop hybrid models) will be investigated and lastly, the economic impact of the proposed methodology will be carried out.

Moreover further forecasting model can be taken in account in order to validate the quality of results obtained.

REFERENCES

[1] CIE 115, "Recommendations for the Lighting of Roads for Motor and Pedestrian Traffic", 1995.

[2] CIE 115, "Lighting of Roads for Motor and Pedestrian Traffic", 2010.

[3] Transport, Environmental and community services committee. "Reducing Energy Consumption - Street Lighting". Report No TEC/87/08. The Highland Council, 2008.

[4] M.S.Rea, J.D. Bullough, Y. Akashi, "Several views of metal halide and high pressure sodium lighting for outdoor applications". Lighting Research and Technology. p. 41(4): pp. 297–320, 2009.

[5] "Intelligent Street Lighting Saves Up to 80% On Energy" , ScienceDaily, July 2011.

[6] "New System of Intelligent Management of Street Lighting Enables 80% Savings in Energy" , ScienceDaily, November 2011.

[7] M.A. Arbib. The Handbook of Brain Theory and Neural Networks, The MIT Press, Cambridge (MA), 1995.

[8] S. Haykin. Neural Networks, "A comprehensive foundation" (2nd edition), Neural Networks, Prentice Hall, New Jersey, 1995.

[9] D. Canca, J. Larrañeta, S. Lozano, L.Onieva, "Traffic intensity forecast in urban networks using a multilayer perceptron". Joint International Meeting, Barcelona 1997.

[10] M.S. Dougherty and M.Cobbett, "Short term inter-urban traffic forecasts using neural networks". Proc. Second DRIVE-II Workshop on Short-Term Traffic Forecasting, Delft, The Netherlands, pp. 65-79, 1994.

[11] S.Ishak, P. Kotha, C.Alecsandru, "Optimization of Dynamic Neural Network Performance for Short-Term Traffic Prediction". In Transportation Research Record, 1836, pp. 45-56. 2003.

[12] D. Park, L.R. Rilett, G. Han "Spectral Basis Neural Networks for Real-Time Travel Time Forecasting", Journal of Transportation Engineering 125(6), 1999, pp. 515-523.

[13] C. Taylor and D.Meldrum, "Freeway traffic data prediction using neural networks". Proc. 6th VNIS Conference, Seattle, WA, pp. 225-230, 1995.

[14] J.W.C. Van Lint, S.P. Hoogendoorn, H.J. Van Zuylen, "Freeway Travel time Prediction with State-Space Neural Networks", National Academies Press, Transportation Research Record 1811, pp. 30-39, , Washington D.C., 2003.

[15] W.Zheng, L. Der-Horng, Q.Shi, "Short-Term Freeway Traffic Flow Pre-diction: Bayesian Combined Neural Network Approach", Journal of Transportation Engineering, 2006, pp. 114-121.

[16] T. Pamula,"Road traffic parameters prediction in urban traffic management systems using neural networks", Transport Problems, Volume 6 Issue 3, 2011, pp. 123-128.

[17] L. Bucur, A.Florea, B.S.Petrescu, "An adaptive fuzzy neural network for traffic prediction", Control & Automation (MED), 18th Mediterranean Conference , Marrakech, pp. 1092 – 1096, 2011.

[18] B.G. Çetiner, M.Sari, Q.Borat, "A neural network based traffic flow prediction model", Mathematical and Computational Applications, Vol. 15, No. 2, 2010, pp. 269-278.

[19] S.Jawanjal, P. Bajaj, "A design approach to traffic flow forecasting with soft computing tools", Emerging Trends in Engineering and Technology (ICETET), 3rd International Conference, pp. 81-84, Goa, 2010.

[20] F. Rosenblatt, "The perceptron: a perceiving and recognizing automaton". Report 85-460-1, Cornell Aeronautical Laboratory, 1957.

[21] F. Rosenblatt, "Principles of neurodynamics: perceptrons and the theory of brain mechanisms". Spartan Books, Washington D.C.,1961.

[22] A. Krogh, J. Vedelsby, "Neural network ensembles, cross validation and active learning", Advances in Neural Information Processing Systems, 7, pp. 231-238, MIT Press, 1995.

[23] Y. Liu, X. Yao, "Ensemble learning via negative correlation", Neural Networks, 12(10), 1999, pp. 1399-1404.

[24] L. Breiman, "Combining Predictors", Combining Artificial Neural Nets - Ensemble and Modular Multi-net Systems, Springer, Berlin, pp. 31-50, 1999.

[25] M.P. Perrone and L.N. Cooper, "When networks disagree: ensemble methods for hybrid neural networks". Neural Networks for Speech and Image Processing, Chapman-Hall, 1993.

[26] C.M. Bishop, "Neural networks for pattern recognition". Oxford University Press, pp. 364-369, 1995.

[27] R. Kohavi and E. Bauer, "An empirical comparison of voting classification algorithms: Bagging, boosting and variants", Machine Learning, 36 , 1999, pp. 105 - 142.

[28] H. Drucker, "Improving regressors using boosting techniques", Machine Learning, Proceedings of the Fourteenth International Conference, pp. 107-115, 1997.

[29] R. Avnimelech and N. Intrator, "Boosting regression estimators". Neural Computation, 11, 1999, pp. 491-513.

 ISBN: 978-1-61208-282-0

Use Cases for Analysis and Energy Effect Based on Energy Management System for Solar Energy at Home

Jeong-in Lee, Chang-sik Choi, Il-Woo Lee
Energy IT Technology Research Section, Smart Green Life Research Dept.
Electronics and Telecommunications Research Institute
Daejeon, South Korea
{jilee, cschoi, ilwoo}@etri.re.kr

***Abstract*— Generally, home energy management system (hereinafter "HEMS") provides energy management consulting service of environment based on digital home environments, and defines the essential requirement. It also provides the guideline of the related technology development and infrastructure. In this paper, we describe the architecture of HEMS and suggest economic analysis and energy conservation effect with the introduction of green home energy management platform in testbed.**

Keywords-Home Energy Management System; Energy Analysis; Energy Conservation Effect

I. INTRODUCTION

The introduction of Smart Grid to the home caused promoting itself to zero-energy management technology and the built-environment related technology development, thus making the management of climate change possible and attaining improvement for the quality of life for citizens. The government provides 1 million green homes by 2018 by supporting the public housing corporation's annual target of 100,000 green homes between 2009 and 2018 and reducing energy consumption in the residential sector by 30% [1].

We develop the home energy management system (HEMS) type of platform for green home, which is composed of home clients (server) and operation (complex home) server. The energy management platform technology for green homes monitors and controls all detailed energy usage to provide an efficient energy management function, which reduces carbon-emission from the house by optimizing the energy consumption such as electric consumption in the home. The aim of the technology is to achieve no-carbon emission in the home, which is based on interfacing the home area network and service and includes IT convergence hardware and software technologies. It consists of an integrated monitoring interface module and energy management framework technologies which provide functions for green energy management, remote energy control, and energy service management.

Testbed for Zero Carbon Green Home located in Korea Institute of Construction Technology (KICT) is R&D project with Electronics and Telecommunications Research Institute (ETRI) and Korea Institute Energy Research (KIER). Testbed is being constructed to conserve energy by active energy technologies (energy management system, renewable energy, etc.) and passive energy technologies (heat-shield, smart-window system, ventilation, etc.). To manage the energy, we are developing Home Energy Management System. HEMS provide energy management and optimization system, connecting devices and equipment that create, store and save energy. Energy flow and consumption within household can be monitored on displays such as wall pad (In-Home Display) by using green home server to connect up smart meter, water meter and smart appliances [2].

In this paper, we provide economic analysis of energy and payback period by using HEMS. We also describe the energy saving for home. This paper is organized as follows. In **S**ection 2, we explain the related works of testbed for the green home. We describe scenario of the energy economic and energy savings when we equipped with HEMS in each household in Section 3, and present our conclusions in Section 4.

II. RELATED WORKS

The home energy management platform technology for green homes monitors and controls all detailed energy usage to provide an efficient energy management function by optimizing the energy consumption such as electric power consumption in the green home test-bed. Green home testbed located in KICT are made of fifteen households on the 3rd through 8th floors and control (operation) center on 2nd floor for total energy management. HEMS is composed of two parts: green home server, which is part of each household, and control center, which covers the entire green home complex with respect to all households energy management [3]. Green home testbed to verify and monitor energy performance had planned to complete by the end of 2012. But, Construction was delayed and completed in March 2013. It been delayed for three month. Figure 1 shows the overview of green home testbed.

 ISBN: 978-1-61208-282-0

Figure 1 . Green home test-bed in KICT

Green home server interacts with advanced metering infrastructure server and green home complex server in order to gather the smart meter measurements such as electricity, gas and water meters and analyse energy usage for each household. The Configuration of HEMS is shown in Figure 2.

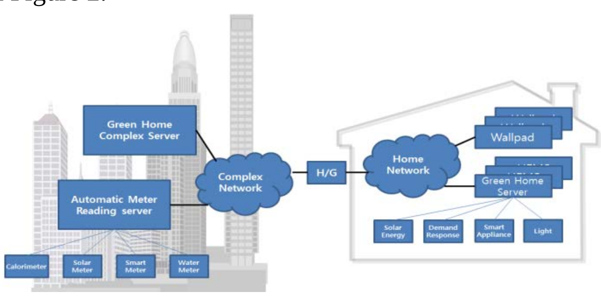

Figure 2 . Composition of home energy management system

Also, green home is a no-carbon emission house in which all required energy for its life is provided by itself based on renewable energy. The testbed is equipped with solar energy and connected to the grid with an installed capacity of 34.66 kW and 34kW solar inverter. It consists of an integrated monitoring interface module with solar energy which provides functions for renewable energy management, remote energy control, and energy service management (see Figure 3).

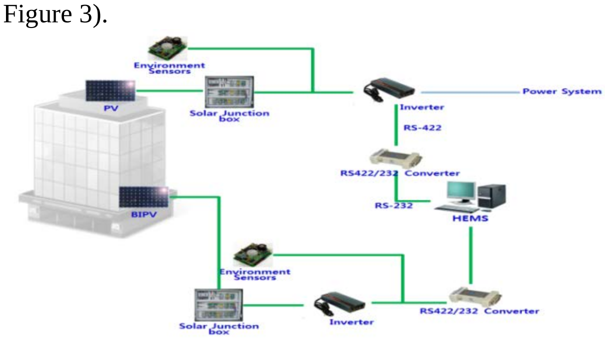

Figure 3 . Green home connected with Solar energy

III. SCENARIO

A. *Conceptual model for analysis*

In this paper, we described the development of HEMS which is interconnecting with various smart appliance and renewable energy. We need to analyze how much energy we save, as much as how much energy we use after we equip each household with HEMS.

To analyze the energy saving, we categorized each testbed based on the size of the floor space. The Energy Consumption of home changes according to testbed floor spaces. The testbed is composed of three floor space: 38.36 ㎡, 62.25 ㎡, 84.75 ㎡. Table 1 shows the electric energy consumption that is classified as monthly and yearly (see Table. I).

TABLE I. ELECTRIC ENERGY CONSUMPTION BY USE

Sort	Floor space (㎡)		
	38.36	62.25	84.75
A monthly average of electric use (kWh)	180.8	235.9	305.8
A yearly average of electric use (kWh)	2,169.6	2,830.8	3,669.6

Testbed was completed in March 2013. It been delayed for three month. For that reason, the interior was not equipped with smart appliances for analysis of energy use. We estimated the energy consumption based on the data of KPX in Table II. The energy consumption patterns are classified into eight types by floor spaces. We choose energy us to compare testbed floor spaces.

TABLE II. ELECTRICITY CONSUMPTION PATTERNS BY FLOOR SPACE

Sort(㎡)	Rate (%)	Electric use (kWh)
Under 33.06	5.4	151.1
36.36~49.59	13.7	180.8
52.89~66.12	19.8	235.9
69.42~82.64	23.4	264.6
85.95~99.17	15.9	305.8
102.48~115.70	15.3	331.7
119.01~165.29	6.1	374.0
Upper 168.6	0.5	448.8

Source : Survey on electric consumption and characteristic of home appliance, KPX, (Oct. 2009)

In this paper, we assume that energy saving rate is an 11.12 percent based on the other project (2012) named ‘smart home network industry infrastructure development’. The other project is now under way in Naju, Korea. It replaced an old-fashioned home network infrastructure with a new one. The other project has no regard for renewable

 ISBN: 978-1-61208-282-0

energy system in home. Figure 4 shows a comparison of the household electric charge before and after the installation of the home area network system.

'Regency Ville Apt., Daeho-dong, Naju-si, Jeollanam-do, Korea

A monthly amount of electric meter (2010) — A monthly amount of electric meter (2011)

Date : 2011-12-15 dhgn 3:14:33

Unit : kWh

	Apartment	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Noc	Dec	Apartment	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Noc	Dec
240	0102-1404	369	414	373	396	395	376	382	446	416	361	389	419	0102-1404	461	494	382	431	388	356	375	454	409	378	381	374
241	0102-1405	384	386	337	346	297	336	335	409	413	357	356	441	0102-1405	480	506	369	462	447	423	410	485	382	341	352	345
242	0102-1406	315	316	259	253	224	202	213	253	226	191	225	251	0102-1406	256	273	250	275	240	230	242	245	246	227	254	257
243	0102-1407	376	431	384	351	334	367	371	467	415	340	400	396	0102-1407	435	460	389	393	371	352	330	400	373	352	388	365
244	0102-1408	147	149	142	164	187	190	179	208	215	226	201	210	0102-1408	195	173	129	157	168	173	177	199	187	181	168	165
245	0102-1501	215	211	190	199	171	146	158	191	200	170	165	171	0102-1501	174	202	247	370	406	338	329	361	359	341	412	471
246	0102-1502	525	623	547	561	513	507	478	422	386	482	529	523	0102-1502	564	598	469	472	449	403	389	493	428	293	436	464
247	0102-1503	215	262	291	341	354	342	364	192	158	147	135	122	0102-1503	133	149	110	137	169	176	184	199	192	158	164	134
248	0102-1504	584	605	536	547	487	468	484	579	501	458	464	447	0102-1504	427	417	407	465	437	415	427	446	437	387	407	427
249	0102-1505	427	415	362	374	382	408	422	538	528	387	344	328	0102-1505	335	404	380	397	400	402	396	476	424	416	414	407
250	0102-1506	412	408	351	375	347	333	341	328	361	322	364	404	0102-1506	455	489	410	421	385	375	355	378	415	367	364	402
251	0102-1507	432	417	371	409	370	393	399	545	460	402	376	403	0102-1507	384	347	272	278	285	288	302	348	345	324	372	379
252	0102-1508	282	263	243	254	247	244	260	276	265	258	266	286	0102-1508	332	337	245	323	302	309	312	385	330	314	328	311
253	0102-1601	230	208	220	249	224	190	150	170	180	210	254	279	0102-1601	322	368	274	262	213	180	180	182	150	206	222	226
254	0102-1602	336	266	293	256	306	258	275	338	319	268	290	304	0102-1602	336	299	345	316	330	387	350	418	425	358	329	402
255	0102-1603	447	504	424	398	415	336	327	408	396	360	448	445	0102-1603	460	500	444	408	355	308	387	464	412	331	331	392
256	0102-1604	297	336	277	246	219	224	177	200	159	194	219	251	0102-1604	269	316	229	278	258	192	208	192	175	234	248	278
257	0102-1605	434	458	287	241	200	187	236	249	255	235	357	388	0102-1605	373	473	386	404	319	299	314	346	357	314	329	384
258	0102-1606	321	333	306	292	310	305	313	359	350	292	329	345	0102-1606	352	371	309	317	337	347	355	406	381	323	318	311
259	0102-1607	320	248	245	259	190	180	135	142	205	260	276	376	0102-1607	389	269	302	326	289	247	259	192	241	229	334	361
260	0102-1608	621	729	596	550	458	256	183	213	211	257	299	255	0102-1608	319	370	280	287	276	245	258	254	217	276	296	223
261	0102-1701	435	443	368	359	343	376	369	435	394	372	383	362	0102-1701	368	417	360	365	378	366	342	402	377	351	365	388
262	0102-1702	117	153	137	135	160	189	213	219	201	183	189	240	0102-1702	226	176	147	156	189	189	174	183	183	165	176	184
263	0102-1703	387	402	373	359	297	281	197	295	284	200	200	197	0102-1703	280	294	241	289	202	196	195	233	249	225	181	177
264	0102-1704	440	431	360	399	411	412	413	538	483	380	371	363	0102-1704	387	396	344	293	232	232	218	539	329	245	210	228
265	0102-1705	255	216	213	200	230	211	265	266	270	250	265	250	0102-1705	306	264	286	296	304	267	291	301	303	270	290	238
266	0102-1706	459	546	354	304	224	36	175	247	247	201	204	162	0102-1706	172	214	163	161	137	142	161	222	229	183	192	182
267	0102-1707	387	394	307	301	296	307	310	377	339	284	304	300	0102-1707	341	385	334	310	313	294	293	309	309	276	289	286
268	0102-1708	655	664	602	653	614	506	627	656	765	644	617	684	0102-1708	675	724	533	569	599	642	598	781	682	648	595	594
269	Total	89,763	94,025	82,437	83,265	81,295	81,230	80,726	98,641	94,394	80,708	83,594	85,240	Total	90,566	96,821	80,488	83,326	82,599	78,600	80,037	96,027	86,291	78,737	81,466	82,409

Figure 4 . The measurement for Electric charge of household

Figure 5 . Green Home Server User Interface

We developed low-power energy metering and control module based on wireless communication (IEEE 802.15.4) for smart appliance. It is plugged to each smart appliance and communicates with green home server [10]. We can check the information measured instantaneous power and accumulated power (see Figure 5).

Since the household is equipped with HEMS, we can check the status of energy usage of home. In Fig. 6, we can see the monitoring of energy consumption for each smart appliance.

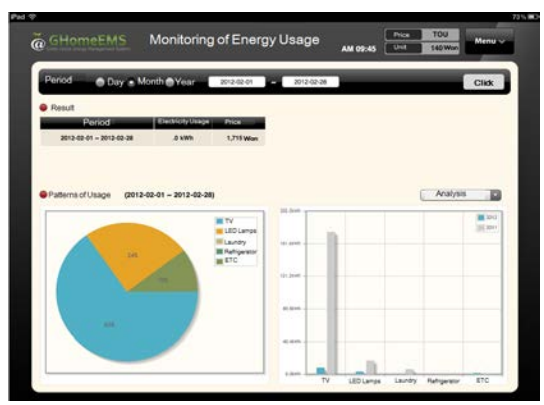

Figure 6 . Green Home Server Consumer's User Interface

B. *Case study energy saving*

In this paper, we calculate the average of energy saving after the home energy platform was installed. We have calculated two averages: a monthly average and a yearly

 ISBN: 978-1-61208-282-0

average. Table III shows the energy saving with HEMS. The larger floor space is the more energy saving than smaller.

TABLE III. ENERGY SAVING WITH HEMS

Sort	Floor space (㎡)		
	38.36	62.25	84.75
A monthly average of energy saving (kWh)	20.1	26	34.0
A yearly average of energy saving (kWh)	241.3	315	408.1
A yearly average of energy saving cost ($/household)	29.55	57.00	106.83

As testbed was equipped with the solar energy, we are considering energy saving with renewable energy.

The capacity of PV module is 34.66kW. The amount of average solar radiation in Korea is 3.92 kWh/㎡·day, total design factor is 0.75. We calculate the amount of solar energy generation. It is 37,193.65 kWh/㎡ and the monthly amount of solar energy generation is 206.63 kWh/㎡ in testbed. Table IV shows the amount of energy consumption when equipped with solar energy. People who live on bigger floor space consume more energy than those who live on smaller floor space.

TABLE IV. THE AMOUNT OF SOLAR ENERGY GENERATION

Sort	Floor space (㎡)		
	38.36	62.25	84.75
A monthly average of energy use (kWh)	-45.9	3.0	65.2
A monthly average of energy saving cost ($/household)	20.88	26.37	38.92
A yearly average of energy saving cost ($/household)	250.51	316.46	467.09

Energy saving of the house increased after the solar energy installed. A yearly average of energy saving cost is $344.69. People who live on the smallest house can sell electricity 45.9kWh each month to utilities companies. Also, the largest house saved quadruple the energy (money) compared to the amount of energy used before the installation of home network. The largest house in testbed will save $467.09 after their installation of solar energy (see Table. IV).

C. *Case stugy economic analysis*

For an economic analysis, we calculate the energy saving with HEMS. We assume the annual electric charge saving is $106.83 in each household because the 84.75 square meters is the average of floor space. Next, we estimate HEMS installation cost when HEMS is universally available in home. As a result, the payback period is 4 years. Table V shows the estimation of total cost and payback period.

TABLE V. ESTIMATION OF TOTAL COST

Sort	Value ($/Household)
Annual electric charge saving **(A)**	106.83
HEMS installation cost **(B1)**	367.65
Measurement and control module for smart appliance **(B2)**	45.96
Total cost **(B=B1+B2)**	413.61
Pay Back period **(C=B/A)**	3.9 year

For an economic analysis, we calculate the energy saving with HEMS and renewable energy. We assume the annual electric charge saving is $467.09 in each household because the 84.75 square meters is the average of floor space. Next, we calculate solar energy installation cost when HEMS is universally available in home. As a result, the payback period is 7.23 years. Table VI shows the estimation of total cost and payback period.

TABLE VII. ESTIMATION OF TOTAL COST (include solar energy)

Sort	Value ($/Household)
Annual electric charge saving **(A)**	467.09
HEMS installation cost **(B1)**	367.65
Measurement and control module for smart appliance **(B2)**	45.96
Solar energy installation **(B3)**	2,962.14
Total cost **(B=B1+B2+B3)**	3,375.75
Pay Back period **(C=B/A)**	7.23 year

IV. CONCLUSIONS AND FUTURE WORK

The Korean government announced an obligatory plan for new houses that mandates 90% reduction in cooling/heating energy consumption starting from 2017 and a zero energy house level starting from 2025. In order to accomplish these goals, passive and active systems need to be in place.

In this paper, we described the development of HEMS, which is interconnecting with various smart appliance and renewable energy. Also, we calculated the average of energy saving by month and year when the home energy platform and renewable energy were installed. These results are expected to contribute the support of the government-driving green home supply project, and reduce the energy saving cost).

For the future work, we will apply energy storage system and electric vehicle charging station in home. They will be controlled and managed by HEMS. And we calculate and estimate energy savings and payback period when installing energy storage system near the future.

KNOWLEDGMENT

This work was supported by the Wide Area Economic Bloc Connection Cooperative Business of Ministry of Knowledge Economy, Republic of Korea, under Grant no.A00450034, "Development of a Module-based Communication and Information Processing Technology".

REFERENCES

[1] Jeong In Lee, Chang-Sic Choi, Wan-Ki Park, and Il-Woo Lee, “Home Energy Management System internetworking with Advanced Metering Infrastructure”, Information and Communication Technology Convergence, pp. 297-297, Oct. 2012.

[2] Lamia Kamal-Chaoui, Fabio Grazi, Jongwan Joo and Marissa Plouin, “The Implementation of the Korean Green Growth Strategy in Urban Areas”, OECD Regional Development Working Papers, Feb. 2011.

[3] Chang-Sic Choi, Wan-Ki Park, Jin-Soo Han, Il-Woo Lee, “The Architecture and Implementation of Proactive Green Home Energy

[4] Management System”, Information and Communication Technology Convergence, pp. 457-458, Nov. 2010.

[5] Hyunwoo Joe, Jaebok Park, Chaedeok Lim, Duk-Kyun Woo, and Hyungshin Kim, “Instruction-Leve Power Estimator for Sensor Networks” ETRI Journal, vol. 30, no. 1,pp. 47-58, Feb. 2008.

[6] Jinsoo Han, Chang-Sic Choi, and Ilwoo Lee, “More Efficient Home Energy Management System Based on Zigbee Communication and Infrared Remote Controls,” IEEE Transaction on Consumer Electronics, vol. 57, no. 1, pp. 85–89, Feb. 2011.

[7] ITU-T Focus group Smart Grid WG1, “Use cases deliverable”, Oct. 2010.

[8] TTAK.KO-04.0127, “Power Grid-HAN Interworking Model for Energy Management”, Telecommunications Technology Association, pp. 1-17, Dec. 2010.

[9] Masahiro Inoue: “Network Architecture for Home Energy Management System“, IEEE Transactions on Consumer Electronics, vol. 49, no. 3, pp. 270-271, Aug. 2003.

[10] ISO/IEC JTC 1/SC 25N 1717, “Interconnection of Information Technology Equipment”, Committee Draft ISO/IEC CD 15067-3, Feb. 2010.

 ISBN: 978-1-61208-282-0

Impact of Incentive Mechanism in Participatory Sensing Environment

Niwat Thepvilojanapong*, Tomoya Tsujimori*, Hao Wang†, Yoshikatsu Ohta*, Yunlong Zhao†, and Yoshito Tobe‡
* *Department of Information Engineering, Mie University*
1577 Kurimamachiya-cho, Tsu city, Mie, Japan
E-mail: {wat, tujimori, ohta}@net.info.mie-u.ac.jp
† *School of Computer Science and Technology, Harbin Engineering University*
Nantong Street No. 145, 21#320, Harbin, Heilongjiang Province, China
E-mail: {halinw, zhaoyunlong}@hrbeu.edu.cn
‡ *Department of Integrated Information Technology, Aoyama Gakuin University*
5–10–1 Fuchinobe, Chuo-ku, Sagamihara city, Kanagawa, Japan
E-mail: yoshito-tobe@rcl-aoyama.jp

***Abstract*—Nowadays, the number of smartphone users is growing rapidly. Recent smartphones equipped with several sensors are convenient apps for collecting information in participatory sensing environment. However, contributing sensing data requires time and monetary cost, which hinder many people from participation. To realize active and efficient sensing activities, incentive mechanism is indispensable. This paper proposes *SenseUtil*, utility-based incentive for participatory sensing. SenseUtil applies the concept of micro economics, where demand and supply decide the value of sensed data. The incentive dynamically changes along the time according to several factors such as sensing frequency, nearby sensing points and users' preference. To study the impact of incentive mechanism, we conducted simulation study. The results show that people actively participate in sensing tasks while keeping additional cost fewer than three percent in comparison with non-incentive scenarios.**

***Keywords*-participatory sensing; incentive; utility functions; phone sensing; SenseUtil; simulation.**

I. INTRODUCTION

The number of smartphone users is growing rapidly [1]–[3]. It has been reported that the smartphone penetration in five leading European markets (France, Germany, Italy, Spain and the United Kingdom) is 54.6% of mobile phone users by the end of October 2012 [3]. In addition to cellular communication standards (2G/3G/4G), smartphones support several communication technologies including Wi-Fi 802.11 a/b/g/n, Bluetooth and near field communication (NFC). It also comes with high-performance processor and various kinds of sensors such as accelerometer, gyroscope, magnetometer, compass, GPS, barometer, microphone, ambient light, camera and so on. These features of current smartphones are useful for many apps which attract new users.

Recently, participatory sensing using such smartphones has been received much attention from researchers [4]. Smartphone sensing platforms, recruitment framework, energy-efficient techniques and several context-aware apps have been proposed in the literature [5]–[9]. However, many smartphone users are not likely to participate in sensing activities because it takes time and monetary cost for data communication. Therefore, incentive mechanism is indispensable to realize *active* participatory sensing by urging people to report sensed data [10], [11].

This paper proposes *SenseUtil*, a utility-based incentive framework for participatory sensing. In this model, *consumers* who need data pay reward to *producers* who carry out sensing tasks and report the data. SenseUtil applies the concept of micro economics, where demand and supply decide the value of sensed data. The demand and supply depend on many factors including location, data types and users' preference, and they also change along the time dynamically. In particular, SenseUtil determines the value of sensing activities by defining utility functions which are used to calculate *economical reward*. SenseUtil aims to maximize sensing activities while maintaining reasonable sensing cost. To study the impact of SenseUtil, we conducted simulation study. The results show that people actively participate in sensing tasks while keeping additional cost fewer than three percent in comparison with non-incentive scenarios.

This paper is organized as follows. Section II describes SenseUtil framework. Section III evaluates the benefit of SenseUtil through simulation study. Related work is discussed in Section IV, and we conclude our study in Section V.

II. SENSEUTIL FRAMEWORK

SenseUtil consists of three main players: consumers, producers and a server. A *consumer* would like to have data being sensed at a remote area, while a *producer* is willing to carry out such sensing tasks. A person can serve as both the consumer and producer. A central *server* is responsible to manage interactions between consumers and producers. Interactions of three players are summarized in Figure 1 and the details of SenseUtil are described in this section.

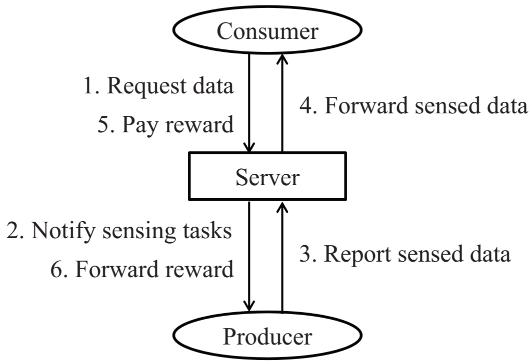

Figure 1. Interactions of a consumer, a server and a producer.

Table I
NOTATIONS.

D^k_{th}	Distance threshold of a producer k
U^k_{th}	Utility threshold of a producer k
T^k_{th}	Elapsed time threshold of a producer k
U	Independent utility
U_{min}	Minimum utility
U_{max}	Maximum utility
V	Correlated utility
P_i	A point of interest (POI) i
t	Current time
t_i	Latest sensing time at P_i
a, α, b	Constants
w_{ij}	Weight for calculating correlated utility
d_{ij}	Distance between P_i and P_j

A. Consumers

A Consumer defines a *Point of Interest (POI)* where data should be sensed. In addition to location information, POI also includes starting time, expiry time and data type (i.e., which kind of data need to be sensed). The consumer sends POI information to the server on demand. When receiving corresponding data, the consumer pays reward determined by the utility functions (see Section II-D).

B. A Server

A server is a middleman between consumers and producers (Figure 1). It maintains POIs' information or the sensing tasks requested by consumers and updates corresponding reward of each POI periodically or on demand. The producers acquire detailed information of sensing tasks by exploiting pull and/or push services.

By adopting the *pull* or *on-demand services*, the server dispatches POI information upon receiving a request from a consumer. The producers may use the pull service to avoid being overwhelmed by too frequent update of POI information. In addition, the producers can use the pull service to update current reward of POI. On the other hand, the *push service* provides two methods for dispatching the information to producers, i.e., instant and periodic push. The *instant push* allows the server to dispatch the POI information immediately upon receiving new POI information from a consumer. The service is beneficial for producers who would like to have the information of new POI in real-time manner; thus, they can act fast to receive rewards. The producers subscribe to *periodic push* will receive the POI information periodically.

The server is also responsible to collect sensing data from producers and forward the data to consumers. In addition, the process of collecting payment and rewarding are handled by the server.

C. Producers

As described above, a producer receives the information of sensing tasks including current reward from the server through pull and/or push services. The producer can also determines her preferences including area of interest (e.g., a limited area based on current position or any specific area), maximum number of tasks, minimum reward, frequency of push-based notification, and so on.

The behavior of a producer depends on current position and reward of sensing task. A producer k will carry out a sensing task if all the following conditions satisfy: (1) her position is not far from a POI, i.e., the distance between the producer and the POI is shorter than or equal to D^k_{th}, (2) the reward is higher than a threshold U^k_{th}, and (3) the time elapsed from previous sensing at the same POI is longer than T^k_{th}. The underlying reason of the third condition is to avoid too frequent sensing at the same POI.

If the above conditions satisfy, the producer changes the route by moving towards the POI, carries out the sensing task and moves towards the original destination. By default, the producer uses the maximum speed in order to minimize moving time. However, the producer may move with the current speed if she is not in a hurry. After the task has been done, the producer receives reward via the server.

Note that the producers may calculate utility by using (1) or (2) introduced in Sect. II-D. However, the producers may have incorrect value of utility because they do not know when other producers carry out the sensing tasks. The producers need to use the pull service to ask for current utility maintained by the server.

D. Utility Functions

This section introduces utility functions which are used to calculate the value of sensing data POI i (i.e., P_i) at a given time t. The consumers have to pay reward according to the utility functions. We consider two cases when calculating utility, that is, independent and correlated POIs. Table I summarizes notations used in the paper.

Independent POI means sensing data of P_i are independent of other POIs. Basically, the utility is initialized to the minimum value (U_{min}) and increases along the time until reaching the maximum value (U_{max}). Equation (1) defines

 ISBN: 978-1-61208-282-0

the utility of POI i at time t.

$$U(P_i, t) = \max\left(U_{min}, \min\left(U_{max}, a(t - t_i)\right)\right), \quad (1)$$

where t_i is the latest sensing time at P_i and is initialized to the starting time of P_i. While sensing task is not done, the utility increases along the time due to higher demand of consumers. A coefficient a ($a > 0$), which is determined by the consumer, determines how fast the utility increases. The consumer also decides U_{min} and U_{max} because the value of data sensed at each POI may be unequal.

When a sensing task has been done, the utility is reset to the minimum value and starts to increase again. The underlying reason of (1) is straightforward. Consumers would like to urge producers to carry out sensing tasks but they would like to avoid too frequent sensing which is not likely to give meaningful information for most of applications. Because some kinds of sensing data do not change abruptly, it would be better to have an interval between each sensing. By applying the above equation, consumers pay less for each sensing if sensing interval is short while they pay more if the interval is long.

Next, we consider *correlated POI*, $V(P_i, t)$, where the utility of P_i correlates to nearby j POIs ((2)).

$$V(P_i, t) = \begin{cases} \alpha U(P_i, t) + \\ \quad (1-\alpha)\frac{\sum_{\forall j} w_{ij} U(P_j, t)}{\sum_{\forall j} w_{ij}} & \text{if } P_j \neq \varnothing, \\ U(P_i, t) & \text{if } P_j = \varnothing. \end{cases} \quad (2)$$

Equation (2) includes the utilities of nearby j POIs, i.e., $U(P_j, t)$ which is calculated by (1) and weighted by w_{ij}. The weight w_{ij} is inversely proportional to the distance d_{ij} between P_i and P_j. In particular, $w_{ij} = \frac{b}{d_{ij}}$, where b ($b > 0$) is a constant. In addition, a constant α ($0 \leq \alpha \leq 1$) is a ratio to determine the weight of P_i and all nearby POIs' utility. If nearby POI does not exist, we use (1), i.e., if $P_j = \varnothing$, $\alpha = 1$.

The nearby j POIs to be considered in (2) are determined by the area centered at P_i and/or the number of nearest POIs centered at P_i. It is explicit from (2) that if the utilities of nearby POIs are high, $V(P_i, t)$ will be high because P_i and nearby j POIs are not sensed for a while. If any nearby j POIs has been sensed recently, $V(P_i, t)$ will be low because nearby POIs are likely to give similar sensing data.

E. Economical Point System

Any kinds of currency including monetary currency, virtual currency and a point system can be applied to SenseUtil for payments and rewards. Point system is widely adopted by real-world stores and electronic commerce for long time and has been proved to be a successful strategy to urge purchasing and maintain loyalty of customers.

III. Performance Evaluation

We conducted simulations to study the impact of incentive mechanism. The simulation program is written in Java language.

Table II
SIMULATION PARAMETERS.

Simulation area (m^2)	500 × 500
Sensing area	%80 of simulation area
Number of POIs	10
Number of producers	10
Minimum speed (m/s^2)	3
Maximum speed (m/s^2)	7
Maximum pause time (s)	9
Simulation duration (s)	1,000
D^k_{th} (m)	24
U^k_{th}	13
T^k_{th} (s)	10
U_{min}	10
U_{max}	50
a	1
α	0.5
b	1

A. Simulation Setup

Mobile users or producers move according to the random waypoint model [12]. Each mobile user is initially placed at a random position within the simulation area. As the simulation progresses, each mobile user pauses at its current location for a random period, which we call the pause time, and then randomly chooses a new location to move to and a velocity between the minimum and maximum speeds at which to move there. The pause time is randomly chosen between zero and maximum pause time. Each mobile user continues this behavior, alternately pausing and moving to a new location, for the duration of the simulation.

Consumers pick random POIs within a *sensing area* which is defined as a percentage of the entire simulation area. The center and aspect ratio of both sensing and simulation areas are the same, i.e., the sensing area is a subset of the simulation area. All POIs last from the beginning until the end of simulations.

The parameters of simulation including those of the random waypoint model and utility functions are summarized in Table II. We run simulation 10 times with different patterns of node movement.

B. Simulation Scenarios

We consider the following scenarios in our simulation.

- **Non-incentive scenario.** Since incentive is not available in this scenario, each node moves according to the mobility model and carry out sensing tasks if they happen to pass through a POI. Based on preliminary experiments, nodes rarely pass through POIs. Thus a sensing task is supposed to be done if a node stays within five meters from a POI in our evaluation (Section III-D).
- **Incentive-aware scenario.** Both of utility models ((1) and (2)) are adopted in this scenario. The nearby j POIs are determined by the circle centered at P_i with the radius of 50 meters. The server uses the push-based

 ISBN: 978-1-61208-282-0

service to announce POIs and corresponding rewards at the beginning of the simulations. When the distance between a producer and a POI is shorter than or equal to the threshold D_{th}^{k}, the producer queries the server about current reward by using the pull service.

C. Evaluation Metrics

The following metrics are useful to study the impact of incentive.

- **Number of sensings.** We count the number of sensing tasks done by all producers in a simulation. The number of sensings is a straightforward metric to evaluate the benefit of incentive. Higher number of sensings means more people help collect sensing data.
- **Paid reward per sensing.** We calculate average reward per sensing in each simulation. Then the percentage of decreased reward when applying incentive is calculated as follows.

$$\%\text{Decrease} = \frac{U_{none} - U_{incentive}}{U_{none}} \times 100, \qquad (3)$$

  where U_{none} and $U_{incentive}$ are average reward per sensing in non-incentive and incentive-aware scenarios, respectively. Note that, we assume incentive is available in non-incentive scenarios for comparison purpose. In particular, we use the same utility models ((1) and (2)) to calculate rewards when nodes are supposed to do sensing tasks. The incentive does not actually exist and nodes move according to the mobility model.
- **Traveled distance.** There is cost to do sensing tasks because producers have to change their routes and take additional time to visit POIs. Thus we compare traveled distance between non-incentive and incentive-aware scenarios. We calculate the percentage of increased distance when applying incentive as follows.

$$\%\text{Increase} = \frac{D_{incentive} - D_{none}}{D_{none}} \times 100, \qquad (4)$$

  where $D_{incentive}$ and D_{none} are average traveled distance per node in incentive-aware and non-incentive scenarios, respectively.

D. Simulation Results

The average results of 10 runs are summarized in Table III which shows both absolute results and relative results in percentage. The detailed results of each run for all three metrics are shown in Figures 2 (the number of sensings), 3 (average reward per sensing) and 4 (traveled distance per node).

The results in Table III show that the number of sensings increases 391% and 375% when adopting independent and correlated incentives, respectively. Figure 2 shows the results of each individual run. As one would expect, incentive urges more people to carry out sensing tasks.

Table III
SIMULATION RESULTS OF 10 RUNS.

	Non-incentive	U	V
Total number of sensings	24.9	122.2	118.3
Increased number of sensings (%)	N/A	391%	375%
Average reward per sensing	46.0	37.6	36.6
Decreased reward per sensing (%)	N/A	18%	21%
Average distance per node (m)	4,638	4,744	4,745
Increased distance per node (%)	N/A	2.28%	2.31%

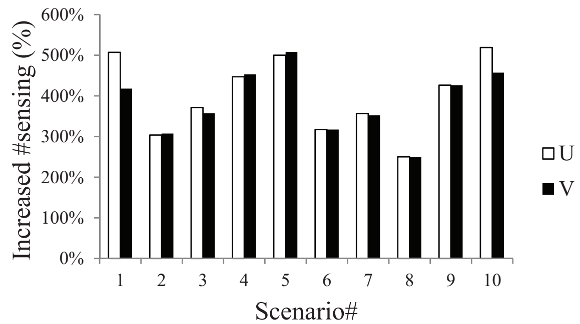

Figure 2. Percentage of increased number of sensing.

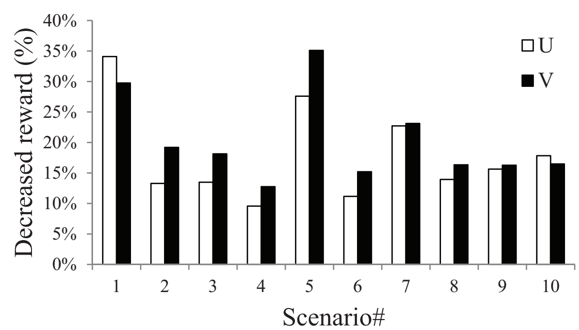

Figure 3. Percentage of decreased reward.

Next we consider the percentages of decreased reward when applying incentives (Figure 3). The paid rewards per sensing decrease 18% and 22% in average when applying independent and correlated incentives, respectively (Table III). The rewards decrease because sensing tasks are done more frequent. We note here that the reward is reset to the minimum value when a sensing task has been done. In other words, it means sensing interval is shorter and sensing data of each POI are updated more frequent. This is a benefit for consumers who pay attention on the freshness of data. In addition, the consumers pay less for each sensing task. When comparing two utility models, the rewards of the correlated model (V) are slightly lower than those of the independent model (U) because the weighted factor α of V is set to 0.5. As a result, the rewards of the correlated model increase slower than the independent model.

The last metric we consider is the percentages of increased distance when applying incentive (Figure 4). The impact of both independent and correlated models is similar in which

 ISBN: 978-1-61208-282-0

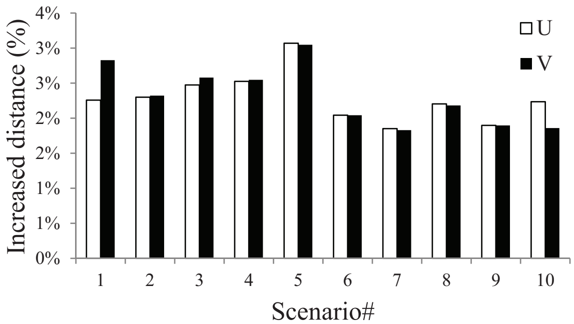

Figure 4. Percentage of increased distance.

the traveled distance increases merely two percent. We can infer from the results that the producers do not need to move much farther than their originally planned routes. In other words, it takes a moment to visit POIs before moving towards the original destinations.

We conclude that incentive is a good motivation to increase sensing frequency. Producers get rewards for their jobs, while consumers pay less for each sensing task in comparison with non-incentive scenarios. Additional cost in terms of traveled distance is also very low.

IV. Related Work

Participatory sensing using mobile phones is an active and growing research area with a number of open issues and challenges [4]. The Internet of Things (IoT), several smartphone sensing platforms, information dissemination algorithms, energy-efficient techniques and context-aware apps, which are the complement of SenseUtil framework, have been proposed in the literature [5]–[9], [13]–[15]. Guo et al. present hybrid social networking, which highlights the interweaving and cooperation of heterogeneous communities [13]. Guo et al. extract the embedded intelligence about individual, environment, and society by exploring the various interactions between humans and the IoT [14]. Askus [15] is a mobile social platform which allows users to send a request to a group of potential people in a remote area to do a task. Similar to Askus, other existing sensing platforms are voluntary systems, i.e., sensing data are contribution from cooperative users. SenseUtil can be applied directly to such previous works.

To realize active and efficient sensing activities, incentive mechanism has been introduced recently. Most of previous works adopt auction algorithms to decide the value of sensing data [10], [11], [16], [17]. Unlike previous works, SenseUtil's consumers indirectly determine their bids through some factors such as minimum price, maximum price, changing rate of price. In addition, the bid price of SenseUtil dynamically changes according to nearby POIs and sensing frequency without any further intervention of consumers.

V. Conclusion

To urge people participate in sensing activities, we have proposed SenseUtil, a utility-based incentive mechanism for mobile phone sensing. SenseUtil introduces utility functions which are used to determine the value of sensing data. When producers finish sensing tasks, they get rewards from consumers according to the utility functions. A salient feature of SenseUtil is dynamic incentive which changes along the time depending on sensing activities of all participants. In comparison with non-incentive environment, the simulation study shows that more people participate in sensing tasks while additional traveled distance of participants is less than three percent.

One of future works is to study the benefit of incentive mechanism by adopting other mobility models. We also plan to include other factors in the proposed utility models and evaluate their impact. Another interesting issue is to let each producer use different conditions to determine whether to do a sensing task.

References

[1] R. T. Llamas and W. Stofega, "Worldwide smartphone 2012–2016 forecast and analysis," IDC Corporate USA, Tech. Rep., Mar. 2012, http://www.idc.com/getdoc.jsp?containerId=233553 (Accessed: January 29, 2013).

[2] M. Meeker and L. Wu, "2012 Internet trends," Kleiner Perkins Caufield & Byers, May 2012, http://www.kpcb.com/insights/2012-internet-trends (Accessed: January 29, 2013).

[3] A. Mohamud, "EU5 smartphone penetration reaches 55 percent in October 2012," comScore Press Release, Dec. 2012, http://www.comscore.com/Insights/Press_Releases/2012/12/EU5_Smartphone_Penetration_Reaches_55_Percent_in_October_2012 (Accessed: January 29, 2013).

[4] N. D. Lane et al., "A survey of mobile phone sensing," IEEE Communications Magazine, vol. 48, no. 9, Sep. 2010, pp. 140–150.

[5] E. Miluzzo et al., "Sensing meets mobile social networks: the design, implementation and evaluation of the CenceMe application," in Proceedings of the 6th International Conference on Embedded Networked Sensor Systems (SenSys 2008), Raleigh, North Carolina, USA, Nov. 2008, pp. 337–350.

[6] S. Reddy, D. Estrin, and M. Srivastava, "Recruitment framework for participatory sensing data collections," in Proceedings of the 8th International Conference on Pervasive Computing (Pervasive 2010), Helsinki, Finland, May 2010, pp. 138–155.

[7] M. Musolesi, M. Piraccini, K. Fodor, A. Corradi, and A. T. Campbell, "Supporting energy-efficient uploading strategies for continuous sensing applications on mobile phones," in Proceedings of the 8th International Conference on Pervasive Computing (Pervasive 2010), Helsinki, Finland, May 2010, pp. 355–372.

[8] T. Choudhury et al., “The mobile sensing platform: An embedded activity recognition system,” IEEE Pervasive Computing, vol. 7, no. 2, April–June 2008, pp. 32–41.

[9] S. Consolvo et al., “Activity sensing in the wild: a field trial of ubifit garden,” in Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2008), 2008, pp. 1797–1806.

[10] D. Yang, G. Xue, X. Fang, and J. Tang, “Crowdsourcing to smartphones: incentive mechanism design for mobile phone sensing,” in Proceedings of the 18th annual international conference on Mobile computing and networking (Mobicom 2012), Aug. 2012, pp. 173–184.

[11] L. Jaimes, I. Vergara-Laurens, and M. A. Labrador, “A location-based incentive mechanism for participatory sensing systems with budget constraints,” in Proceedings of the IEEE International Conference on Pervasive Computing and Communications (PerCom 2012), Mar. 2012, pp. 103–108.

[12] D. B. Johnson and D. A. Maltz, “Dynamic source routing in ad hoc wireless networks,” in *Mobile Computing*, T. Imielinski and H. Korth, Eds.Kluwer Academic Publishers, 1996, ch. 5, pp. 153–181.

[13] B. Guo, Z. Yu, X. Zhou, and D. Zhang, “Hybrid SN: Interlinking opportunistic and online communities to augment information dissemination,” in Proceedings of the 9th International Conference on Ubiquitous Intelligence and Computing and 9th International Conference on Autonomic and Trusted Computing (UIC–ATC 2012), Washington, DC, USA, Sep., 2012, pp. 188–195.

[14] B. Guo et al., “From the internet of things to embedded intelligence,” World Wide Web Journal, Sep. 2012, pp. 1–22.

[15] S. Konomi et al., “Askus: Amplifying mobile actions,” in Proceedings of the 7th International Conference on Pervasive Computing (Pervasive 2009), Nara Japan, May 2009, pp. 202–219.

[16] J.-S. Lee and B. Hoh, “Dynamic pricing incentive for participatory sensing,” Pervasive and Mobile Computing, vol. 6, no. 6, Dec. 2010, pp. 693–708.

[17] ——, “Sell your experiences: a market mechanism based incentive for participatory sensing,” in Proceedings of the IEEE International Conference on Pervasive Computing and Communications (PerCom 2010), Mar. 2010, pp. 60–68.

Many Faces of Mobile Contactless Ticketing

Jonathan Ouoba
LaBRI-University of Bordeaux
Bordeaux, France
jonathan.ouoba@labri.fr

Erkki Siira
VTT Technical Research Centre
Oulu, Finland
erkki.siira@vtt.fi

Abstract**—Smart cities must offer innovative mobile services in the areas of transport and culture. In this context, the ticketing services, which are key elements in the domains of transport and culture, have to be provided. In this respect, the impact of technological developments, including those related to NFC (Near Field Communication), which is a short range wireless technology, lead to the deployment of mobile contactless solutions. We highlight, in the paper, seven models to manage all or part of mobile contactless ticketing systems within smart cities. This study is based on the research conducted in the contactless ticketing area and on the return of experience gained within a European project. The models, which give a realistic picture of the various faces of such systems, are: the operator-centric model, the manufacturer-centric model, the identification-based model, the peer-to-peer model, the smart card-based model, the leeched smart card-based model, and the inverse reader model. We detail the characteristics of each model and present use cases. Furthermore, we present tracks indicating that these models may coexist within smart cities and we derive some perspectives on the evolution of these ticketing services by explaining that two models could be dominant.**

Keywords-mobile services; mobile ticketing; contactless; NFC

I. INTRODUCTION

The concept of *smart cities* refers to cities that have consented to invest in information and communication technologies so that innovative services can be deployed to facilitate the operations of daily life for the citizens [1]. Within smart cities, information and communication technologies are used to improve the legacy systems in the areas of transportation, education, commerce, culture or administration while preserving their successful integration into the urban environment of the end-users.

The mobile phone has become an ubiquitous tool to interact with smart cities services, because of its penetration within the population. For example a citizen could use the same mobile equipment to pay for transit ticket (for a bus) and view the real-time traffic of buses. Thus, smart cities, through mobile services based on new technologies, must provide their citizens with services in the areas of transportation, education, commerce, and culture. In the domains of transport and culture, a key parameter is the ticketing management system. Indeed, access to means of transport or to events is determined by the fact that the users hold valid tickets. The ticketing services are therefore essential and mobile-based solutions must be developed.

One of the promising technologies for the mobile services is the contactless technology. The vision is that smart cities can exploit this technology in the domains of transportation and culture to offer ticketing services. The trick is that the end-user only touches dedicated equipment with the mobile phone, accepts the transaction and gets the access to the proposed service. This is, in our terminology, an example of mobile contactless city services. Mobile contactless services in smart cities are and will be based on Near Field Communication (NFC) [2], which is a wireless technology that takes its roots in Radio Frequency Identification (RFID). It has a range of about 10 centimeters. NFC offers three modes of operation: reader/writer, peer-to-peer and card emulation. The reader/writer mode makes it possible for NFC devices to interact with passive NFC tags. The peer-to-peer (P2P) mode supports direct communication between NFC devices, and the card emulation mode allows a NFC device to act as if it were a smart card. In the latter case, in order to store sensitive data, NFC devices offer support for an embedded smart card chip that is called a secure element.

In the framework of the Smart Urban Spaces (SUS) European project [3], we explored the possibilities offered by the NFC technology in the field of mobile ticketing for city services. The question that arises is: what are the different models of efficient NFC-enabled mobile ticketing systems that can be deployed in smart cities. The aim of our work is thus to present and analyze systems dedicated to mobile contactless ticketing that we consider relevant in the context of smart cities. In the remaining of the paper, we first propose an overview of some research projects regarding the concept of contactless ticketing. Then, in section III we give a description of the key elements in the environment of mobile contactless ticketing while section IV presents the different models, used to provide the ticketing services, which we choose to highlight. Finally, in section V we delineate some perspectives to understand the possible evolution of mobile contactless ticketing services before concluding.

II. STATE-OF-ART IN CONTACTLESS TICKETING

Ticketing systems aim at proposing solutions with electronic tickets (e-tickets) and paperless operations. The use of NFC is one of the most appropriate options to provide such systems. We present here some projects, in the domains of transportation and events management, which are representative of what is done for contactless ticketing.

 ISBN: 978-1-61208-282-0

A. The domain of transportation

Public transport operators are very keen on deploying contactless e-ticketing systems. For example, the Oyster card in London [4] and the Yikatong in Beijing [5] are transportation cards based on the MIFARE technology [6]. As another example, in Hong Kong, the Octopus Card [7] is a transport operator card based on the FeliCa technology [8]. MIFARE and FeliCa are contactless cards technologies. In these systems, the loading of tickets is done either online or via dedicated machines. Then, the users get access to the stations just by touching specific readers with their cards.

Another interesting project is the Virtual Ticketing application. Indeed, by taking advantage of the NFC technology, Ghiron et al. [9] proposed a ticketing application for transport in Rome. In the developed prototype, the virtual tickets are stored in a mobile equipment which is used to perform the different operations. The French transportation company Ligne d'Azur in collaboration with the Cityzi project in Nice offers a similar service for buses [10]. With a dedicated mobile application loaded on a mobile phone, the users are able to buy tickets and validate them by using NFC.

More generally, Widman et al. discuss in [11] the integration of NFC ticketing systems into existing transport infrastructure. Such systems can be successfully integrated by considering, among other things, the following points: the distribution of the application, the distribution of the tickets, the display of the tickets (to inform the user), and the procedures of inspection (to check the validity of presented tickets). The relevance of the scenario is demonstrated by applying the concept to the VDV (Association of German Transport Companies) Core Application.

B. The domain of events management

The events e-ticketing initiatives that rely on the use of contactless technologies are very limited. However, these initiatives demonstrate the added value of NFC in ticketing services. An interesting project is the Tapango system [12], implemented by the Artesis' research lab. It is an electronic voucher system based on e-Wallets with the use of NFC smart cards or NFC-enabled mobile phones. The objective of the system is to reduce the use of paper tickets. With Tapango, the users first buy tickets via a web interface. Then, at the event location they synchronize their e-Wallet (by interacting, through their cards or their mobile phones, with a machine connected to the Internet) to "physically" obtain the tickets and finally they can present the acquired tickets to get access to the show.

Another interesting example is the pilot [13] related to events ticketing in the theatre of the city of Oulu (Finland) that was deployed in the framework of the SmartTouch project [14]. At the theatre site, the users interacted with specific equipment in a point of sale to receive the purchased tickets on their NFC-enabled phones. The inspection of the presented tickets was achieved with another NFC-enabled mobile phone by using the NFC peer-to-peer mode.

III. MOBILE CONTACTLESS TICKETING ENVIRONMENT

Contactless card environment was brought to mass market in 1997 when Hong Kong introduced their Octopus card system. The same contactless smart card standard (ISO/IEC 14443) has been carried to the mobile contactless world so that NFC devices can interact and communicate with compatible contactless smart cards and readers. This backward compatibility gives the already existing ecosystem a domain to tap into.

The card emulation mode of NFC, which offers a support for a secure element, is the one that has been designed to be used with ticketing. There are several options for the secure element. The two most prominent are the embedded secure element option where the secure element is controlled by a manufacturer and the UICC (Universal Integrated Circuit Card) option where the secure element is controlled by a mobile network operator. The strict control of the secure element is essential to ensure the security of the chip, but it prevents an efficient utilization of the chip by 3rd parties. In section IV we present different ticketing models, some of them require a restricted platform and thus make use of the secure element.

A Gartner predicts that in 2015 50% of smart phones would be equipped with NFC [15]. This means that mass market ticketing schemes can start adopting mobile contactless ticketing but, at the same time, it cannot abandon the current plastic card infrastructure. SMS-based and web-based ticketing solutions are already so cost-efficient, that mobile contactless ticketing needs to find its edge somewhere else. User experience is usually considered to be the selling point for contactless services and the ticketing domain should be no different.

IV. MODELS FOR MOBILE CONTACTLESS TICKETING

Due the complexity of mobile contactless ticketing environment, there are many possibilities on how to develop solutions. In this section, we present seven different ways that seem most relevant, in the context of smart cities, to manage mobile contactless ticketing systems.

A. Operator-centric model

GSMA is the global association of network operators that has created a model to build mobile contactless services which ticketing is one of. The GSMA's operator-centric model is based on the use of an UICC as a secure element [16][17]. The use of UICC, which is inserted in a mobile device, gives operators the control of the mobile contactless ecosystem. Because there are several operators and service providers would like their services to be available for all possible customers, the operator-centric model requires the use of an entity called the Trusted Service Manager (TSM). TSM creates an interface for service providers so that they can seamlessly deploy the ticketing applications via this interface, which hides the diversity of operators. TSM can also be the actor that is really in contact with the customer UICC by using the security keys provided by the operators.

As the services are in the UICC, they are transferred along when the consumer changes his or her mobile device to another. An acknowledged problem with this model is the still undefined process of secure element roaming when the user travels in countries with another operator's network. In others words, the problem is to know how the home operator would update and communicate with the secure element in a roaming context. The architecture of the model is presented in the Fig. 1.

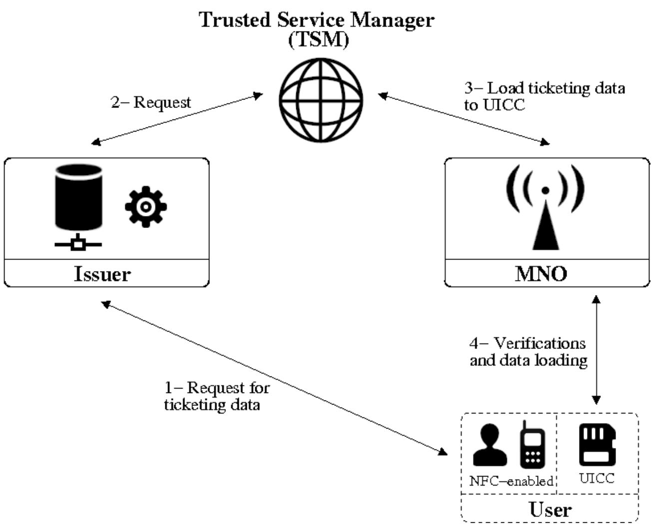

Figure 1. Architecture of the operator-centric model

The operator-centric model is in operation for example in France which is a pioneer of NFC ecosystems with the Cityzi smart city initiative. The operator-centric model is the closest to the industry standard at this time. The major players are behind it and NFC Forum, as a standardization body in the NFC ecosystem, has promoted it as well. Transport For London deployed a mobile contactless ticketing pilot in 2012 [18]. They considered it to be a failed one because the read-speed of ticket when using the UICC as a secure element was too slow for them. Current Oyster card operates at speed of 300ms but the operator-centric model was not able to achieve a validation speed of 500ms that has been considered as a limit for smooth ticketing.

B. *Manufacturer-centric model*

Similar to the operator-centric model is the manufacturer-centric model in which an embedded secure element (in the mobile equipment) is used the storage of sensitive information [16]. The embedded secure element is controlled by the manufacturer. The architecture of the model is presented in the Fig. 2.

For the consumer they seem to be quite similar and most of the difference appears when the consumer changes his or her mobile device (to use the mobile phone of another manufacturer) and the services cannot be transferred in the process. As the model is operator agnostic, the user may change his or her operator easier. The manufacturer-centric model is championed by Google currently. Nokia was also formerly involved in the promotion of the model, but it changed to the operator-centric model.

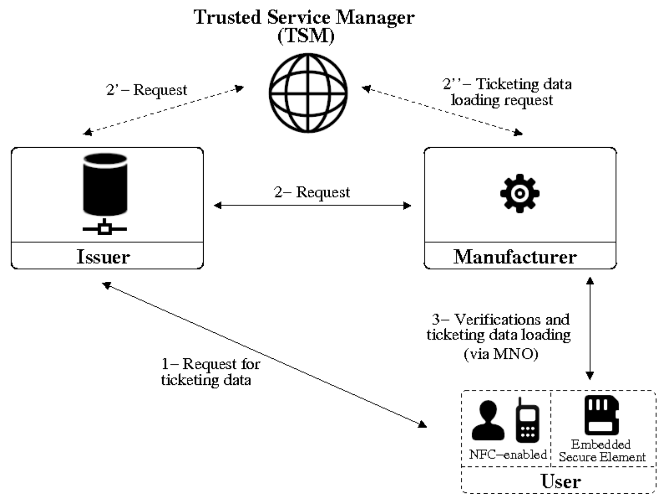

Figure 2. Architecture of the manufacturer-centric model

In practical way, the manufacturer-centric model is used in the Google Wallet –application where the sensitive data is stored in the embedded secure element of Google compliant mobile phones.

C. *Identification-based ticketing*

Identification-based ticketing tries to circumvent the need to store dynamic information in the device of the user. In this context the ticket can be seen as dynamic information which changes for every separate ticketing case. The assumption is that there is a static identifier stored in the secure element of the user's mobile device. The same static identifier is also stored in the ticket issuer's backend system where all the dynamic information is processed.

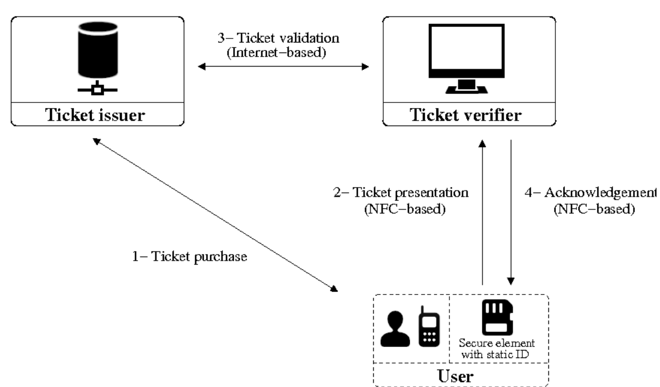

Figure 3. Architecture of the identification-based model

This ticketing system requires a secure element to be available in the user's mobile device so that the static identifier can be stored. This secure element may be a UICC or another secure element that is embedded in the device. The ticketing architecture is described in the Fig. 3. At the gate, the right to enter is verified by reading the identifier from the secure element of the user's mobile device and then sending it to the ticket issuer's system. It returns the authorization (or not) to enter. When the user buys a ticket for a specific event from a ticket issuer, the ticket is stored in the ticket issuer's back end system and it is connected to the static identifier stored in the user's mobile device secure element. The identifier-based ticketing model is used in Oulu (Finland) where the city card chip ID is the relevant key to manage the access rights. Thus far, only smart cards are commonly used but the mobile phone use has already been tested [19].

D. Peer-to-peer ticketing

Peer-to-peer ticketing does not offer the same level of security than the one that can be achieved, for example, with the operator-centric model. However, it excels in creating a light-weight open ticketing system without the need of big companies that control the market with secure elements [20].

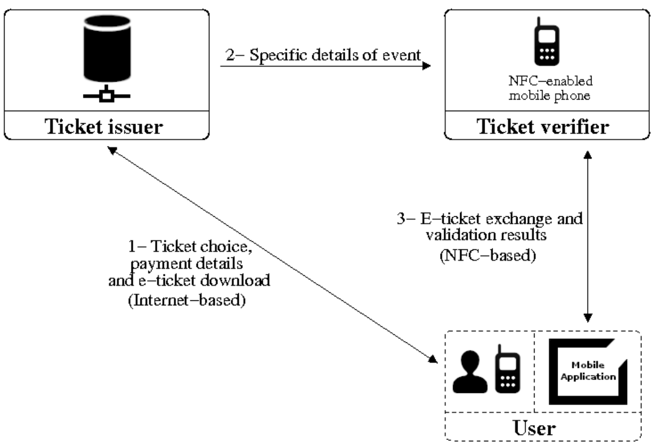

Figure 4. Architecture of the peer-to-peer model

In the peer-to-peer model, the ticket is stored in the user's phone memory when it is bought over the air. During the validation phase, the NFC peer-to-peer functionality is used to transfer the ticket from the user's mobile device to the validator's mobile device where the ticket's validity is checked as described in the Fig. 4. The validator device must keep track of the presented tickets and must contain the mechanisms to check the validity of the tickets. This procedure is made possible by the fact that the validator application is provided, beforehand, with the necessary information regarding the validation process.

This ticketing model was tested and piloted in Bordeaux during social events of computer science conferences and projects meetings (among the pilots deployed during the SUS project).

E. Smart card –based mobile ticketing

Smart card –based mobile ticketing is the model which is the closest to the legacy model of ticketing. The basic infrastructure, which is composed of a smart card and a reader, is changed into an infrastructure with a smart card and a mobile device. The description of the architecture, where the ticket issuance is not considered, is presented in the Fig. 5. The functionalities are the same and the great benefit is that the old legacy (smart card-based) systems can work with new mobile devices equipped with the reader technology. Mobile devices that require a human being to operate them are not economically feasible in comparison to the automatic readers used in public transportation. The advantage comes from having a mobile platform that can be deployed at small costs anywhere. This light-weight approach is suitable, for example, in events where there is a temporary need to have personnel on the field.

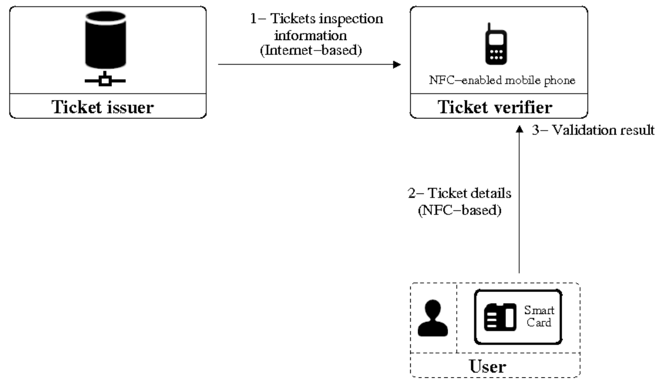

Figure 5. Architecture of the smart card-based model

This model has been deployed in Turku, Finland, where inspectors have used mobile phones when inspecting tickets in busses and other public transportation vehicles (among the pilots deployed during the SUS project).

F. Leeched smart card –based ticketing

The leeched smart card –based ticketing model is founded on the principle that the general populace has already a variety of plastic cards which can be transport cards, payment cards or loyalty cards. This medium can be used as an identifier platform that is linked to a ticket that is stored in the back end system.

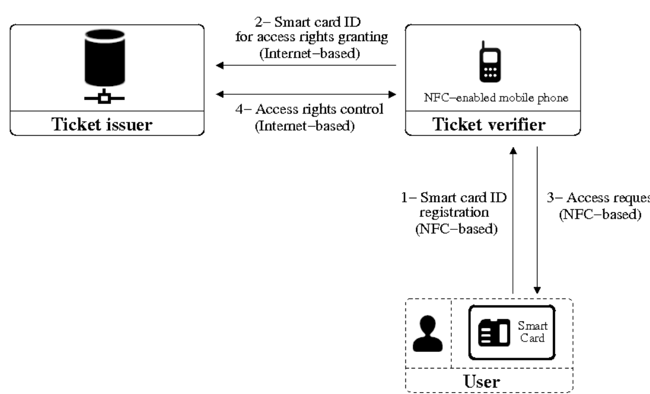

Figure 6. Architecture of the leeched smart card model

An example of this ticketing model was piloted during the Open Europeans 2011 sailing event where Helsinki

Region Transport –card was used as a ticketing medium [21]. There were two technical options: to use the card ID or the ID of an application stored in the card. The latter was chosen as Helsinki Region Transport Authority wanted to test its feasibility. In addition, the users used the public transportation with the same card.

The validation of the ticket is done by a mobile phone. A validating person reads the identifier from the smart card with his or her mobile device. The identifier is sent to the back end system where the validity of the ticket is checked. The information is then returned back to the mobile device where the screen shows if the ticket was valid or not. All this process is presented in the Fig. 6.

G. Inverse Reader ticketing

Saminger et al. [22] are suggesting that reversing the architecture of ticketing could be a possible way to go around the secure element problem. As the mobile device environment is closed regarding the secure element architecture, the inverse reader ticketing achieves the validation process through a NFC mode mismatch.

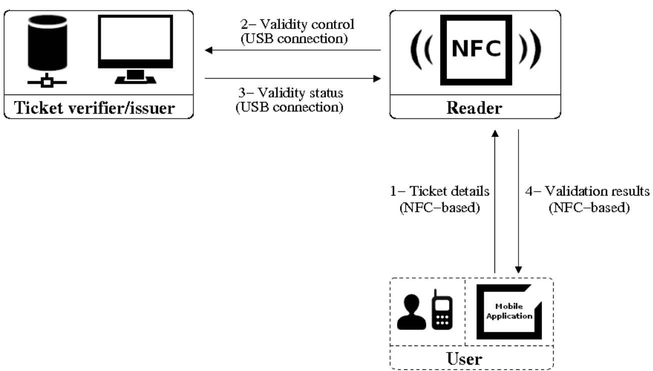

Figure 7. Architecture of the inverse reader model

The system works in a way that the mobile device is in reader/writer mode and the reader, which is linked to a server, operates in card emulation mode (Fig. 7). The ticket itself is stored in the mobile device. When the ticket is presented, the server checks the validity and returns the information to the mobile device. The advantage of this solution lied in the good level of interoperability, in the coverage of interoperable reader/writer mode, and in the use of a light-weight protocol stack of card emulation.

H. Summary

Table I and Table II integrate the 7 models presented for the mobile contactless ticketing options. To highlight their differences and their specificities, the proposed tables provide an overview of the models regarding different classification categories.

TABLE I. DIFFERENT MOBILE CONTACTLESS TICKETING MODELS

Ticketing model	***Customer device***	***Reader device***	***Place of ticket***
Operator-centric model	Mobile phone	Ticket reader	UICC
Manufacturer-centric model	Mobile phone	Ticket reader	Embedded SE
Peer-to-Peer ticketing	Mobile phone	Mobile phone	Phone memory
ID-based ticketing	Mobile phone	Mobile phone	Back end server
Leeched smart card –ticketing	Smart card	Mobile phone	Back end system
Smart card-ticketing	Smart card	Mobile phone	Smart card
Inverse reader ticketing	Mobile phone	Ticket reader	Phone memory

TABLE II. DETAILS OF DIFFERENT MOBILE CONTACTLESS TICKETING MODELS

Ticketing model	***Need of network***	***Contactless protocol***	***Suggested usage***
Operator-centric model	No	Card emulation	All ticketing (too slow for transport?)
Manufacturer-centric model	No	Card emulation	All ticketing
Peer-to-Peer ticketing	No	Peer-to-Peer	Small event ticketing
ID-based ticketing	Yes	Card emulation	Non-transport ticketing
Leeched smart card –ticketing	Yes	Tag reading	Event ticketing
Smart card-ticketing	No	Tag reading	All ticketing
Inverse reader ticketing	Yes	Tag reading / card emulation	Non-transport ticketing

In our opinion, the relevant categories are: the customer device, the reader device, the place of the ticket, the need of network, the contactless protocol, and the suggested usage.

V. WHAT'S IN THE FUTURE?

The diversity of situations an end-user may encounter and the compliance with its preferences makes it necessary to provide mobile contactless ticketing systems of different types. It is also essential for the proposed (innovative) solutions to be interoperable with legacy systems. These elements allow us to assume that the presented ticketing systems can coexist. For example, an end-user, with the same mobile phone, could use a peer-to-peer system to attend a small exhibition while he would use a secure element -based system to store a ticket to a concert.

However, we also assume that MNOs and manufacturers of mobile phones, because of their economic power, can put forward (what they already do) the operator-based and the manufacturer-based models. They have many customers and they can, somehow, impose their rules on some practices. It is currently unclear which of the two models could eventually be preeminent. We can still note that in some

 ISBN: 978-1-61208-282-0

areas, notably the transportation domain, infrastructures are difficult to change (due to the costs of investments and the practical problems of passenger flow) which does not make obvious the possibility of imposing rules on some practices.

In our opinion, the challenge lies in being able to present a clear and coherent picture of the environment so that the end-users can easily understand what the most suitable service is in each possible situation. In the case the different models coexist, it will probably be necessary to provide a service aggregator adapted to the context (automatic selection of the proper application, interoperability between the applications, etc.) in order to foster the user friendliness and keep the end-user at the center of the process.

VI. Conclusion

One characteristic of smart cities is the possibility to grant a person a right to do something. These rights are usually controlled by tickets which represent proofs of entitlement. For example, a transport ticket gives its holder a right to travel to a given destination. Mobile contactless ticketing aims at making the ticketing systems smarter and easier to use.

There are several models available to manage mobile contactless ticketing. We have presented seven different models that are already in use or are in proof-of-concept phase. The presented models are: the operator-centric model, the manufacturer-centric model, the peer-to-peer ticketing, the ID-based ticketing, the leeched smart card model, the smart card ticketing model, and the inverse reader ticketing model. The first two models are the industry pushed models and they should become more prominent. The other five models are suitable for smaller and more focused use cases and will certainly coexist in the smart cities environment.

The role of the secure element will continue to pose problems in the future if the relevant stakeholders do not cooperate in building a robust and clear ecosystem for ticketing. This situation opens a room for the existence of non-secure element ticketing solutions which should excel regarding friendliness aspects to be profitable.

Acknowledgment

We would especially like to thank all the partners of the Smart Urban Spaces (SUS) project with whom we have been working for 3 years and whose valuable contributions have made this work possible.

References

[1] G. Rudolf, C. Fertner, H. Kramar, R. Kalasek, N. Pichler-Milanovic, and E. Meijers, “Smart cities, ranking of european medium-sized cities”, Vienna Centre of Regional Science, 2007.

[2] E. Haselsteiner and K. Breitfuss, “Security in Near Field Communications (NFC)”, Semiconductors, vol. 11, 2006, p 71.

[3] “The Smart Urban Spaces Project”, [Retrieved: 2013, april], [Online] Available: http://www.smarturbanspaces.org/.

[4] “Oyster card”, [Retrieved: 2013, april], [Online] Available: https://oyster.tfl.gov.uk.

[5] “BMAC Card”, [Retrieved: 2013, april], [Online] Available: http://www.watchdata.com/transportation/10150.html.

[6] “MIFARE MF1S5009, “ NXP, 2010.

[7] “The Octopus card”, [Retrieved: 2013, april], [Online] Available: http://www.octopus.com.hk/home/en/index.html.

[8] “The Felica page”, [Retrieved: 2013, april], [Online] Available: http://www.sony.net/Products/felica/.

[9] S. L. Ghiron, S. Sposato, C. M. Medaglia, and A. Moroni, “NFC ticketing: A prototype and usability test of an NFC-based virtual ticketing application”, Proceedings of the First International Workshop on Near Field Communication, 2009, pp. 45-50.

[10] “The B Pass page”, [Retrieved: 2013, april], [Online] Available: http://www.veolia.com/fr/realisations/b-pass-billet-electronique.htm.

[11] R. Widmann, S. Grunberger, B. Stadlmann, and J. Langer, “System Integration of NFC Ticketing into an Existing Public Transport Infrastructure”, Proceedings of the 4th International Workshop on Near Field Communication, 2012, pp. 13-18.

[12] J. Neefs, F. Schrooyen, J. Doggen, and K. Renckens, “Paper Ticketing vs. Electronic Ticketing Based on Off-Line System 'Tapango'”, Proceedings of the Second International Workshop on Near Field Communication, 2010, pp. 3-8.

[13] O. Rouru-Kuivala, “Vision: Touching the Future of ticketing”, VTT Research notes 2492, 2009.

[14] “The SmartTouch project”, [Retrieved: 2013, april], [Online]. Available: http://ttuki.vtt.fi/smarttouch/www/?info=intro.

[15] “NFC Smartphones and Physical Access Control Systems”, [Retrieved: 2013, april], [Online] Available: http://blogs.gartner.com/mark-diodati/2011/10/31/how-soon-is-now-nfc-smartphones-and-physical-access-control-systems/.

[16] Gerald Madlmayr, Josef Langer, and Josef Scharinger, “Managing an NFC Ecosystem”, Proceedings of the 7th International Conference on Mobile Business, 2008, pp. 95-101.

[17] GlobalPlatform White Paper, “The GlobalPlatform Proposition for NFC Mobile: Secure Element Management and Messaging”, April 2009.

[18] “Transport For London pilot”, [Retrieved: 2013, april], [Online] Available: http://www.pcworld.com/article/256397/.

[19] T. Tuikka, E. Siira, and M. Saukko, “City service discovery and access with near field communication”, Proceedings of the 5th International Conference on New Trends in Information Science and Service Science, 2011, pp. 116-121.

[20] S. Chaumette, D. Dubernet, J. Ouoba, E. Siira and, T. Tuikka, “Architecture and Evaluation of a User-Centric NFC-Enabled Ticketing System for Small Events”, Proceedings of MobiCASE, 2011, pp. 137-151.

[21] “Open Europeans 2011”, [Retrieved: 2013, april], [Online] Available: http://www.forumvirium.fi/en/project-areas/smart-city/smart-urban-spaces/open-europeans-2011-helsinki-ended.

[22] C. Saminger, S. Grünberger, and J. Langer, “An NFC Ticketing System with a new approach of an Inverse Reader Mode”, Proceedings of the 5th International Workshop on Near Field Communication, 2013, pp. 1-5.