Internet of Things
Success Stories

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SMART ACTION
Innovating beyond IoT

IERC
European Research Cluster on the Internet of Things

Edito
by Philippe Cousin

On the positive side of the Internet of things "story", we have got every day news with forecast on how the Internet of Things represents an important phenomenon, that will change our lives making everything "smart". It is also reported that IoT brings important fields of opportunities, aiming to boost our economies, create businesses in particular in stimulating (disruptive) innovation. For instance, amongst many studies, Gartner in a December 2013 forecast stated: The Internet of Things will include 26 billion units installed by 2020. IoT product and service suppliers will generate incremental revenue exceeding $300 billion, mostly in services, in 2020. It will result in $1.9 trillion in global economic value-add through sales into diverse end markets. On a more realistic side, we also heard about successes more in vertical markets, which do not show evidence on truly mass market with horizontal approaches. Many voices also are expressed with concerns on privacy, security and interoperability just to mention few blocking factors.

Working within the Internet of Things European Research Cluster (IERC) and even exploring more potential with the cross-fertilization with other sciences (e.g. nanotechnologies, biotechnologies and cognitive sciences), we are enthusiast: We are aware of all exiting possibilities of new business and applications developed within all our research projects and demonstrated by industrial partners in many real pilots such as in smart cities. Positive experiences in using IoT for a broad range of application exist but are shared widely enough. Business confidence in IoT is important to stimulate IoT adoption by the market stakeholders. We need to increase awareness on IoT positive sides.

Let's show our successes in using IoT !

This book is the first of a series which will be an open space for business market stake-holders such as SMEs, but also for researchers to present their success story on how IoT can be used in a particular field to successfully and often in a cost-effective manner, solve a particular problem (eg saving energy, improve heath care, reduce costs).

Enjoy the reading and stay tuned for the next series in 2014 and 2015.

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Foreword

by Peter Friess

One year ago the emergence of the Internet of Things (IoT) was still considered with a certain degree of scepticism. These days are gone as a series of announcements from major players have made IoT an increasingly tangible business opportunity.

From the European Commission's point of view it would be a serious mistake to believe that the game is over for IoT. Europe has already for over six years directly invested in supporting Research and Innovation in the field of IoT, notably in the areas of architectural frameworks, embedded systems and cyber-physical systems, network technologies, semantic interoperability, privacy and security, and generic enablers. Part of these results presented in this book are now feeding innovation, and a series of freely available components and solutions in pilot state can usefully be exploited and enhanced by the market.

As we move on the IoT ecosystem perspective has emerged as a new approach for fostering IoT development in Europe, in particular towards a network of all relevant players involved, addressing the bigger picture together with Cloud technologies and Big data concepts, for enabling a hyper-connected society, where not only a technology push but also considerations of trust, creative practises and ethical aspects are pivotal.

Peter Friess
European Commission,
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by Dr. Pedro Jose Marron

Research on topics related to the Internet of Things (IoT) has been gaining momentum throughout the past years at an enormous pace. After many discussions, papers and research projects, tangible results are starting to appear. This is extremely exciting since the potential of IoT can now be perceived outside of the research communities through the successful completion of pilots and prototypical implementations of technology all over the world. The book you have in your hands is the first of a series documenting success stories of European projects related to IoT and will be followed by further books.

However the successful completion and reporting of these stories does not mean that the research community is holding still. As the coordinator of SMART-ACTION, a European Coordination Action on IoT, I am proud to say that Europe is pushing the limits of IoT and providing the scientific basis for the further integration of IoT technologies into other areas such as nanotechnology, bio-medicine or cognitive science, bridging the gap between technology aspects and the societal challenges created by new technologies such as IoT.

So stay tuned for further developments and success stories! The journey has just begun!

Prof. Dr. Pedro Jose Marron
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Intelligent Waste Management

BURBA: Bottom Up selection, collection and management of URBAn waste with intelligent waste containers (IWAC)

A success story in intelligent waste management
Short title: *BURBA intelligent waste container*

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ABSTRACT: *The paper presents a success story for a connected IOT enabled sensorized intelligent waste container developed in the frame of the BURBA project financed by the EU FP7 program. The Life Cycle Assessment of the Intelligent waste container shows that its environmental impacts are counterbalanced by its benefits. The business model and target market are presented.*

KEY WORDS: *Urban waste management, MSW municipal solid waste, RFID, PAYT, PET recycling.*

1. Problem

The collection and management of urban solid waste is an emergent issue all over the world. European directives have set goals for urban waste separation and recycling. Only few countries in EU till now were able to attain the goals. The improvement needed to reach the EU targets request economically and environmentally viable solution to motivate the citizens, to sustain their efforts in separating at the source, to provide economically viable self sustained solutions allowing waste to become an economical resource. The current waste management has many limitations.

On the waste collection companies side:

- The waste collection is routinely scheduled and cannot adequately answer to erratic daily/weekly oscillations and variations, also on the occasion of calendar events as well as special events (Saturday soccer game, Christmas time, spring break, summer vacation).
- The peripheral sorting of waste is inadequate (many errors by citizens mixing up different types of waste)
- Feed of waste for reaching scheduled recycling percentages is not sufficient/efficient
- The routing of pick-up trucks is not optimized.
- The best location of street containers to minimize costs (truck personnel work time and fuel expenditures) is difficult to estimate because of lack of quantitative and qualitative data.
- The containers are displaced by by-passers (needing room for parking for example) or vandals

On the citizen side:

- Peripheral sorting is based on the good-will of citizens which is often confronted with overfilled containers or inappropriate locations, or new location of specific waste sorting container in new areas without any appropriate information directing the citizens to them.
- Citizens have no feedback about their efforts in waste sorting (how much is in reality recycled appropriately) and have no direct individual (or at the level of building administration) economical benefit. The BURBA project allows for individual computing of waste sorting effort and therefore can allow for a reward system like discount rates on waste disposal fare and taxes.
- The matching of waste to the appropriate container is difficult, instructions are confusing, colour of container is different from one town/county/country to another, packaging and pictograms are not standardised for waste sorting

On the side of Industry producing waste subject to regulation for its disposal

- Since companies are becoming more and more responsible for the environmental and waste impact of their products, in part due to Regulatory frameworks, a system that allows for full tracking from production down to disposal of their products and supporting pre-collection adequate sequestration/sorting is evidently very helpful.
- Feed of waste for reaching scheduled recycling percentages is not sufficient/efficient

The urban household waste collection services evolved in the recent decades from traditional fixed rates systems to those commonly named Pay By Use (PBU) or Pay as You Throw (PAYT). These economical instruments appear to improve waste separation by the citizens (EUNOMIA 2011) (OECD 2013)Waste statistics and figures about the waste charging approach effects in Germany indicate that there is a relatively good correlation between the level of recycling and the amount of perceived financial motivation provided by PAYT (Bilitewski 2008).

The scope of the PAYT schemes is to increase the waste separation and to improve recycling rates in line with European Commission Policy and Directives (EC 1994; EC 2013, EC 2008).

In these schemes the citizen is charged for the amount of waste he/she disposes of. This can be achieved through weight charge, volume charge or by tagged sacks.

The Intelligent Waste Container developed in the frame of the BURBA project thanks to the funding by the European Commission through the FP7 program allows to adopt any of these billing approaches to implement a PAYT policy. Further improvements on separation rates could be achieved by an improvement of waste related services, for example by personalised incentives and feedback (Timlett *et Al* 2008) and by container attributes (Lane *et Al* 2013).

Other factors whose interplay can influence the separation propensity of citizens are related to logistics, frequency of collection, awareness and sensitisation campaigns, as presented by Gallardo (Gallardo *et Al* 2012) for the Spanish case.

Also the appearance and design of waste containers can positively influence the separate disposal rate. In the research of Duffy (Duffy *et Al* 2009)the use of specialized container lids increased recycling compliance rate by 34% and reduced the amount of contaminants entering the recycling stream by 95%.

This is the main target of BURBA technologies that include software applications that allow to monitor the effects of PAYT schemes and of actions for improvement of separation of municipal solid waste.

2. Solution

BURBA project developed an innovative method of optimization of the waste management through the application of RFID and LBS technologies integrated into an intelligent waste container (IWAC) of 600/1200 litres of capacity for its use in densely populated areas.

RFID is exploited at multiple levels in the BURBA project.

The IWAC (Intelligent Waste Container) will be able to identify the citizen/user through a personal RFID card, to control (e.g. lock/unlock) the lid and, therefore, to give feedback about the correct disposal by the user. The IWAC is able to identify items marked with RFID tags or at preset time waste sacks RFID tagged. The IWAC itself is marked with an RFID for redundant identification in case of failure of electronics.

Taking advantage of RFID's ability to reliably identify individual/groups of users/citizens and the kind of waste being disposed, as well as if it is correctly separated, municipalities can create incentive-based recycling programs that accurately reward customers for the amount they recycle and/or charge proportionally to the amount of the generated waste (so called PAYT schemes), while minimizing the amount of trash headed for the landfill.

In the very next future, when single items will be RFID tagged, all data gathered by the system will allow improved market studies and the provision of information about path and life of products, under the property privacy warrantee terms.

The system is designed and built in a modular way so that a commercial version with reduced RFID capability is produced and adapted for immediate use with waste sacks RFID tagged.

The IWAC exploits load cells in the wheel case to weigh the container and the waste disposed this allows planning of IWAC emptying and for optimization of the path of the trucks.

By automating the collection of all waste, the IWACs GNSS/RFID enabled system can assure that individual containers have been emptied, providing verification of service. This information in addition with positioning capabilities ensured by GNSS inside the IWAC are used to optimize truck usage and routes, redirecting and rescheduling the recollection activities for example in case of main events as World Expos or undesirable natural events. With a fully automatic data collection system based on RFID and supported by LBS, versus manual methods, waste management systems can be made more efficient and environmental friendly.

Additionally, under the assumption of comprehensive deployment of RFID tags, it can be expected that in a close future almost every item will have its own RFID for identification and classification at the time of disposal.

With a system capable of automatically recognizing the type of waste being disposed by the user, clearly the waste management is improved reducing wrong waste disposal which affects adversely the environment, leading to higher costs for the cleaning teams and reducing the quality of the recycling process.

The system supports the citizen in appropriate sorting and disposal of waste and, on the other hand, it will also be able to monitor the amount and kind of waste in the waste containers together with its status and location and send this information to a control centre where all the information about all the containers is collected. The same information will be available to the citizen through his/her cellular phone. For instance, the citizen can decide to drop the waste in any available container still having available storage room (considering the kind of waste accepted by the container) on his route while driving to his working place or other destination. Also she/he will receive feedback about her/his environmental efforts and rewards/prices for virtuous behaviour or discounts on the garbage fee.

3. Business model

3.1 "BURBA®" product and technical features

The Design and Implementation and the present implementation stage allows us to state that the developed BURBA System fulfils the BURBA Dow statement: "The system will be designed and built in a modular way so that a commercial version with reduced RFID capability could be produced and adapted for immediate use with non RFID tagged single commercial items". This approach and its successful implementation is exploitable from the stand point of reaching as many clients as possible and to satisfy their sundry specific needs.

This chapter presents the product BURBA in terms of Software and Hardware features and the foreseen configurations obtained by combining the different scalable features.

In the next paragraphs the BURBA system will be split in two main categories:

- The IWAC hardware configurations
- The software configurations

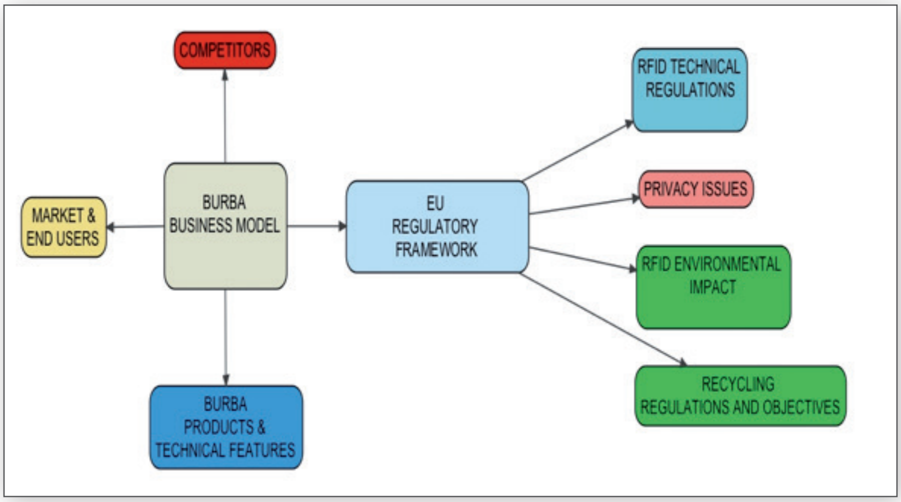

Figure 1. *BURBA business model logic.*

3.2 IWAC Hardware configurations

The BURBA hardware is basically composed by two main parts: the IWAC (Intelligent Waste Container) and the IRN.

The IRN is the communication module between the IWACs and the control centre. Since the IRN architecture is standard and fixed, we assume that it will be always the same in every possible BURBA configuration. On the hardware side, the modular and customisable element of the system is the IWAC number 1.

The BURBA solution foresees an Intelligent Waste Container (IWAC) that includes an electronics box, various sensors, an RFID antenna, a battery, an electronic lock, a LEDs panel, GPS and a solar panel. The modularity of the system allows the customisation for different clients implementing different waste collection and waste payment schemes, and different kind and sizes of the containers. The electronics box can be sold separately from the waste containers and easily adapted to those already in use by a specific client for its own specific services and goals. On the basis of the end-users needs and on the basis of the future evolution of the use of RFID for tagging single items we identified four IWAC hardware configurations suitable for the market.

A basic version suitable for the integration in the current waste management collection and management practice and three evolved versions for the adoption either in the specific areas in which RFID tagged items are already in use (for example special medical waste, or paper documents RFID tagged) or for the adoption in the next future in relation to the foreseen widespread use of RFID tags at the single item level for the mass markets of commercial goods. The basic version will have the capability of reading RFIDs at short range. This is needed basically to read an RFID card that allows for the opening of the IWAC lock and/or an RFID tag sticker on the waste sack to be disposed of (this allows to correlate the weight of the sack to the RFID tag and to the user identity whereby users buy or are given stickers).

The reason for the basic version feature is that nowadays RFID technology has not yet reached a market mass diffusion in the every day life, and the mass commercial goods aren't tagged.

More in details the RFID reading capabilities of the basic version are related to different kind of RFID supports available on the market for different uses:

- Smartphones (like Google Nexus S) that feature and RFID for e-payments
- RFID sticker on waste sack
- RFID personal "waste card"
- Any RFID card (external to the BURBA system) to be provided by prospective specific parties interested in the exploitation of BURBA as an advertising or promotional vector, i.e. Shop fidelity card, public transportation card etc that can include "virtuous behaviour" rewards or other enticing rewarding scheme. These interested Parties could also be those interested in collecting data for marketing research.

The implementation of the RFID reading feature of the BURBA system Basic version, requires only a short range RFID reader since the RFIDs four options, presented in the previous lines, will be at close range of less than 30 cm. Low cost short range RFID antennas are available on the market. This allows for a cheaper commercially viable basic version.

The electronics of the basic version includes an RFID lock and RFID reader module, a transmission module, volume sensor and a solar panel.

This basic version is suited for the integration in the present Waste Collection and Management practices of the European Municipalities, without need of major changes in waste containers, waste collection trucks, crew tasks and work flow, as well as citizens habits, and last but not least waste fee payment schemes, related facilities and means available

So far this configuration allows for the production of a commercial version that could be adopted by the prospective customers at the present time.

This basic version is named for commercial and marketing scopes "Ultra Light".

It fully responds to the present market needs and to the increasing adoption by the municipalities, Europe wide, of PAYT schemes (Pay for What You Throw). It is a cheap version for immediate translation of the prototype in to an industrialised model for production and commercialisation, although it is simplified in comparison to the evolved versions in that the electronics components are reduced to the essential.

The evolved versions that have been named Light, Standard and Full, are intended for the use in the next future, when all the mass production commercial items will be tagged.

In the table below the four different configurations of the IWAC are summarised.

Feature	Ultra light	Light	Standard	Full
RFID lock	☼	▲	▲	▲
RFID reader module	☼	▲	▲	▲
Transmission module	☺	☺	☺	☺
Weight sensor	☺	☺	☺	☺
Volume sensor	☺	☺	☺	☺
Temperature sensor			O	☺
Humidity sensor			O	☺
Accelerometer		☺	☺	☺
LEDs panel			☺	☺
GPS		☺	☺	☺
Solar Panel	☺	☺	☺	☺
Other sensors on demand				O

O = optional
☺ = included
☼ = economic short range RFID reader
▲ = full capabilities RFID reader

Table 1: *IWAC configurations*

The BURBA system was also fitted to 240 litres containers that can be deployed in strategic areas of city centre such as parking lots and wall niches. This “mini IWAC” is an over simplified version otherwise its price could not be counterbalanced by the economical and environmental benefits derived from the improved waste management and collection path. Compared to the HW part, there are more degrees of freedom regarding the possibility to fulfil the customer needs because the software can be easily customizable.

For example, if a municipality buys a Light version of the SW, with reduced features but much affordable, in a future, he can easily expand the bought SW with an upgrade.

Software configurations

The main purpose of the SW architecture is to provide a system capable of integrating the BURBA HW components with a Back-Office system that will enable the management of different aspects such as waste collection, number of IWACs, monitoring of IWAC levels and more efficient resource management. There is a plurality of different subjects such as citizens, truck fleet managers, researchers, municipalities that needs to interact with the BURBA system. This can be possible through the BURBA portal using a variety of devices (i.e. fixed or mobile).

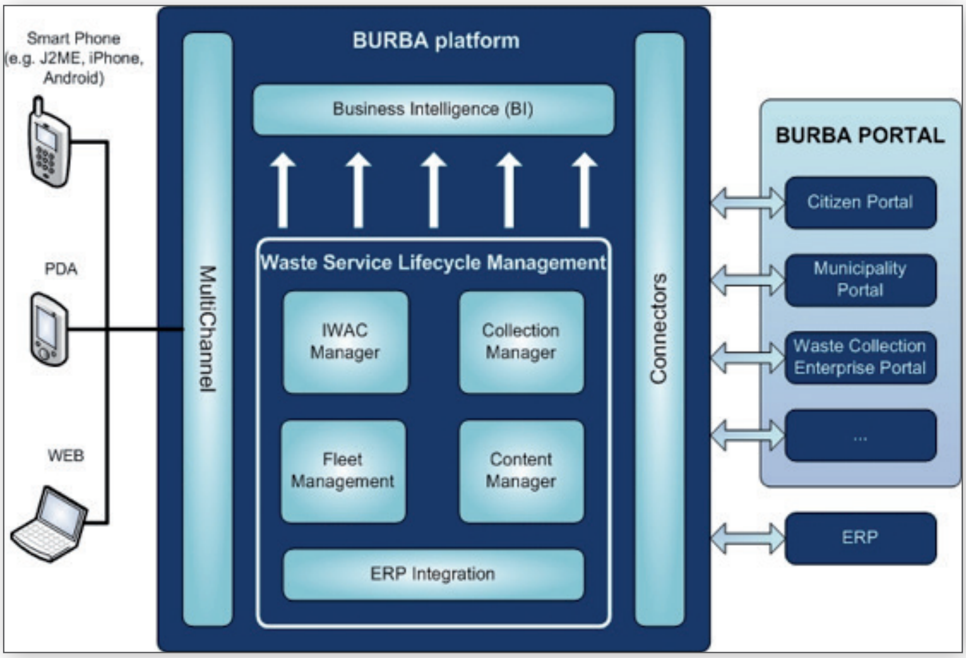

Figure 2. *BURBA software architecture.*

The BURBA software pack (see Figure 2) includes two main parts: the Platform and the Portal.

Compared to the HW part, there are more degrees of freedom regarding the possibility to fulfil the customer needs because the software can be easily customizable. For example, if a municipality buys a Light version of the SW, with reduced features but much affordable, in a future, he can easily expand the bought SW with an upgrade.

More in details in the following table (Table 2) we present the basic configurations of the software. The main purpose of the SW is to provide a system capable of integrating the BURBA HW components with a Back-Office system that will enable the management of different aspects such as waste collection, number of IWACs, monitoring of IWAC levels and more efficient resource management. There is a plurality of different subjects such as citizens, truck fleet managers, researchers, municipalities that needs to interact with the BURBA system. This is possible through the BURBA web portal.

Components	Light	Standard	Custom
Web server	☺	☺	☺
User account component	☺	☺	☺
Multi-language component	☺	☺	☺
Commercial services component			☺
Complaint manager component		☺	☺
Special events component			☺
Clean crew manager		☺	☺
Surveillance video camera manager			O
Quantitative goals component			O
IWAC manager		☺	☺
Waste collection manager	☺	☺	☺
Notification/Feedback component		☺	☺
Fleet manager		☺	☺
Business Intelligence	☺	☺	☺
Content manager component		O	☺
External Systems		O	O
Other o.d.		O	O

O = optional
☺ = included

Table 2. *BURBA software versions.*

Market segment: Municipalities

Municipalities are the main client target of our solution. In this chapter we focus on the type of public administration of interest and an estimation of its market size is provided. The market needs for solutions like BURBA has been formulated for municipalities that:

- need to simplify their service interaction models;
- need to achieve the EU objectives in urban waste recovery/recycling
- need to shift to a new waste payment scheme;
- need to offer new services;
- lose money because they cannot implement a better waste scheme collection and improve efficiency;
- need to achieve a higher citizen motivation and participation in the environmental themes;
- citizens with access to internet.

The BURBA solution will enable Public Administrations with the above profile of needs to define their services more accurately and allows them to achieve better integration with citizens. BURBA targets municipalities of any type and size (central/large, regional/medium and local/small) willing to endorse e-government policies.

3.4 Municipalities market size projections

Currently, municipalities in Europe are classified as LAU21, according to EUROSTAT and EU sources.

In the European Union, LAUs are basic components of Nomenclature of Territorial Units for Statistics (NUTS) regions. For each EU member country, two levels of Local Administrative Units (LAU) are defined: LAU-1 and LAU-2, which were previously called NUTS-4 and NUTS-5 respectively, until the NUTS regulation went into force in July 2003.

A quantitative estimation of the target market is possible to be made with the presumption that Eurostat estimates the number of local administrative units is around 110.000 in the EU-27, with an additional 40,000 in the EFTA and candidate countries.

These public bodies include prefectures, states, municipalities, counties, district councils, local governments and local public unions of any form. Not all of the 110,000 local and 1.671 regional authorities have the same needs for new models of waste scheme collection. However, as the EU directive imposes with regard to preparation for reuse and recycling a minimum of 50% for at least paper, metal, plastic and glass from households and possibly from other origins and at the actual stage many EU countries need to improve. For example in 2008 (EU 2009) the EU countries presented the following situation:

Belgium, Germany and the Netherlands > 50% of recycling; Austria, Denmark, Luxembourg, Norway and Sweden 40%-50%; Ireland, United Kingdom, Finland and France 25%-40%; Italy and Portugal 10%-25% and but with a very high (> 0. 75 percentage point) yearly increase since 2000.

Greece and Spain have similar figures of 10%-25% but have a modest (< 0. 75 percentage point) yearly increase since 2000.

Regarding the new EU member countries, we have Czech Republic > 30% level of recycling, Bulgaria and Romania > 20% level of recycling, Cyprus, Estonia, Hungary, Latvia, Malta and Slovenia 10%-15%, Lithuania, Poland and Slovakia < 11%.

In Italy in 2010 (ISTAT 2010) the percentage of Municipal solid waste separation was only 31.7 % in the 116 Municipalities Chief of Province i.e. the bigger towns. At a more detailed analysis only 34 out of 116 have passed the 50% threshold (that by the Italian Law is set to 60% for MSW separation and has been reached in 2010 only by 13 Municipalities Chief of Province)

On the basis of these data we assume that at least 50 % of the 30,400 local and regional Public Authorities in Europe (EU 27) will have a greater need for waste management models, tools and E-services such as those one offered by BURBA capabilities also in terms of money saved by using an integrated service and also in terms of fines for not having reached the EU objectives.

BURBA can support the increased need of separation, whose improvement anyway takes quite a long time with the current schemes and technology, being usually an improvement of a small percentage per year (1-2%).

4. Underlying Magic: the Life cycle Assessment (LCA)

There is really something magic in the BURBA: the results of the Life Cycle Assessment when used in a model to compute the break even point between between environmental impacts and the benefits obtained in the frame of an improved waste separation and collection service.

This results are beyond any expectation: the environmental debt due to the electronics component of the BURBA system can be paid back in 6 days.

The BURBA intelligent waste container is devised to support PAYT schemes and to improve service to the citizens with the ultimate goal of supporting the progress toward the achievement of the European Directives targets for waste separation and recycling.

One relevant issue for the introduction of any new "green" technology, is to assess if it is really green, i.e. if the claimed environmental benefits, such as "improved separation and collection of recyclable waste" are counterbalancing its environmental impacts.

Here we present the details of the LCA of the BURBA system and of the break even point evaluation.

Following the EC recommendations, the ILCD Life Cycle Impact Assessment Methods have been used, which comprise 16 impact categories at midpoint level. Additionally, we performed the Carbon Footprint Analysis (CFA) following the Greenhouse Gas Protocol (GGP) and the Cumulative Energy Demand (CED).

The computed impacts of the BURBA system were compared to those of a traditional waste container.

As expected, the presence of battery and electronics in the BURBA system, in comparison to the traditional waste bin, produced an increase in every impact category although the predominant source of impact was the plastic mainframe.

According to the results of the LCA, we show that the excess quota of environmental impacts in respect to a standard waste container can be entirely compensated by the environmental benefits of a small increase of the municipal household solid waste separation at the source, begot by the improved service to the citizens. The present study answered to this critical question presenting the case of the intelligent waste container for the improved separation of PET bottles.

5 Life Cycle Assessment (LCA) results and discussion

5.1 Comparison of the environmental impact of BURBA with that of the traditional waste container

The next table reports the difference in terms of environmental impacts compared to that of the IWAC.

IMPACT CATEGORY	DIFFERENCE
Climate change [kg CO2 eq]	6,80E+01
Ozone depletion [kg CFC-11 eq]	1,34E-05
Human toxicity, cancer effects [CTUh]	3,40E-06
Human toxicity, non-cancer effects [CTUh]	1,29E-05
Particulate matter [kg PM2.5 eq]	4,20E-02
Ionizing radiation HH [kg U235 eq]	3,25E+01
Ionizing radiation E (interim) [CTUe]	8,40E-05
Photochemical ozone formation [kg NMVOC eq]	2,50E-01
Acidification [molc H+ eq]	6,90E-01
Terrestrial eutrophication [molc N eq]	7,70E-01
Freshwater eutrophication [kg P eq]	3,16E-03
Marine eutrophication [kg N eq]	6,90E-02
Freshwater ecotoxicity [CTUe]	6,60E+01
Land use [kg C deficit]	7,20E+01
Water resource depletion [m3 water eq]	2,29E-01
Mineral, fossil & ren resource depletion [kg Sb eq]	3,73E-02

Table 3. *Environmental impacts of the IWAC as per LCA.*

As expected, the IWAc is more impactful than a standard HDPE waste container. This is because of the presence of the battery and the electronics. The categories in which the impact is more significative are: Land use, Climate change and freshwater ecotoxicity. According to this first analysis, the BURBA system appears to be more polluting than standard HDPE containers. The next paragraphs shows that the major impact of BURBA can be easily compensated through triggering citizens' virtuous behaviours.

5.2 Are the impacts identified through the LCA counterbalanced by the environmental benefits?

The main objective of EU directive 2004/12/Eci (EU 2004), amending directive 94/62/EC, on Packaging and Packaging Waste is to prevent packaging waste by encouraging packaging re-use and recycling while at the same time avoid distortions in the internal market. The directive requests that Members States introduce systems for the return and/or collection of used packaging and defines specific targets for packaging waste recovery and recycling. The targets defined are the following:

Recovery of minimum 60% by weight of the packaging waste

Recycling of at least 55% and a maximum 80% by weight of the totality of packaging materials, with a material-specific minimum recycling rate for plastics of 22.5%.

In some EU countries the Percentage of recycling of PET bottles is quite high (Switzerland, Germany, Norway, Sweden). In others (Poland, Bulgaria) is still under the thresholds of the EU Directives (EC 2013, EC 2008)

We evaluate here if the surplus of environmental impact of the BURBA system compared to that of standard HDPE waste container could be counterbalanced by other factors, such as an increase of the percentage of recyclable separated materials.

We compute the potential benefits of the adoption of the BURBA IWAC considering the study case of PET bottles hypothesising different percentages of their separation by the citizens disposing of them in a IWAC dedicated bin. It is possible to extend this methodology of evaluation also to other recyclable materials, like glass, paper and aluminium.

The rationale for the adoption of the IWAC is that its use in the frame of PAYT schemes will provide a better service and support the willingness of the citizens to dispose of the recyclable household waste separately so far increasing the percentage separated. The BURBA systems has many features that enable a better service: cell phone application for feedback to the citizen about the costs, about how much he/she contributed to preserve the environment (such as reduced CO2 emissions), support to PAYT scheme for big curb side container but with individual responsibilities and accountability, positive rewards such as discounts or bonuses, nearest IWAC available information through cell phone or internet, IWAC that are emptied before denying service or being overwhelmed by waste disposed thanks to improved recollection by trucks.

5.3 Study case of PET bottles

Polyethylene terephthalate, commonly abbreviated PET, is a thermoplastic polymer resin of the polyester family widely used to make containers for carbonated and non-carbonated soft drinks.

In this section we evaluate the PET recovery percentage needed in order to pay off the environmental costs of the IWAC and if this is compatible with the attitudes and behaviours of the users.

5.3.1 Assumptions

For this study case, we considered the waste collection for a neighbourhood of 1000 citizens.
Each inhabitant produces every day an average of MSW quantified in 1,47 kg, with a density of 106 kg/m3 iv.

If we assume that:

- the collection is carried out once a day
- the waste containers are completely full at the moment of the waste collection
- the waste containers have a volume of 1100 l

It follows that the minimum number of waste containers necessary to fulfil the needs of a neighbourhood of 1000 citizens is 13.

According to a recent survey, about 1,7% of the composition in mass of MSW is composed by dense plastic bottles. A 2003 study from Recoup Association indicates that the 42% of the waste generation of dense plastic bottles is made from PET. So, in this study case, the estimated production of PET bottles could be quantified in 10,5 kg/day.

The study of Chilton (Chilton *et Al* 2010) evaluated the environmental impact of the process of recycling PET compared to that of the manufacture of brand new virgin PET.

The related figures are presented in Tab. 4.

Pollutant	Kerbside collection	MRF	Transport to PET cleaning	PET cleaning process	Transport to preform manufacture	Bottle manufacture	Offset PET manufacture	Total
CO2 [kg]	8,2	9,0	3,8	160	20	9,3	-1900	-1700
CO [kg]	0,05	2,9	0,01	36	0,06	3,3	-110	-68
Nox [kg]	0,10	0,02	0,03	0,25	0,07	0,03	-1,3	-0,80
SO2 [kg]	0,0006	0,03	0,002	0,43	0,03	0,04	-1,7	-1,2
Hcl [g]	0,056	0,009	0,095	0,33	0,50	0,01	-28	-27
Particulates [g]	0,064	2,4	1,7	33	9,1	3,2	-82	-33
VOC [g]	56	0,4	0,01	5,0	18	0,41	-19000	-19000
NH3 [g]	0,0012	0,0001	0,003	0	0,02	0,001	-0,41	-0,39
Pb [mg]	1,0	0,06	13	0	68	0	-470	-390
Cd [mg]	0,11	0,02	0,24	0,04	1,3	0	-230	-230
Hg [mg]	0,014	0,003	0,049	1,4	0,26	0,001	-30	-28
Dioxins [μg]	0,002	0,0009	0,0005	0,011	0,002	0,0011	-0,054	-0,037

Table 4. *Environmental impacts of recycling PET (per tonne of PET managed) (from Chilton et Al. 2010).*

5.3.2 Results

As an example of the environmental capabilities of BURBA, considering the figures of the study of Chilton *et Al*. (2010) we hypothesized 3 solutions for arranging the waste collection in the considered scenario:

A) All the waste is collected unsorted with 13 standard waste containers

B) PET bottles are collected with different percentages; the collection is organised with 12 standard waste containers for MSW + 1 IWAC for PET bottles

C) PET bottles are collected with different percentages; the collection is organised with 12 IWACs for MSW + 1 IWAC for PET bottles

For each scenario we computed the environmental impact expressed in Kg of CO2 eq:

	A: 13 standard HDPE waste containers	B: mixed system: 12 standard HDPE WC + 1 IWAC FOR PET	C: 12 IWAC for MSW + 1 IWAC for PET
Type of collection	100% unsorted	Recovery of PET bottles	Recovery of PET bottles
N° of IWACs	0	1	13
N° of STD waste containers	13	12	0
Kg of CO_2 eq.	3510	3578	4394
Difference with solution A [Kg]	/	+ 68	+ 884

Table 5. *Environmental impact for the different waste collection solutions.*

Can an improvement in PET recovery provide such a sparing in CO2 production so to counterbalance the CO2 increase due to the production of the IWAC?

To answer this question we assessed whether the greater environmental impact that occurs in solutions exploiting the IWACs may be compensated through the environmental savings due to a higher collection rate of PET bottles.

The table indicates the time, expressed in days of use, necessary to achieve the “break even point” between a waste collection organised only with standard waste containers and the two alternatives solutions with a different number of IWACs and with a variable percentage of PET bottles collections.

In addition, is presented the time necessary to cover the surplus of CO2 production with respect to the solution with only standard waste containers.

To perform these calculations it is assumed that all the amount of CO2 eq saved thanks to the PET collection is used to counterbalance the environmental debt of the waste collection solution considered.

PET Collection %	Kg of PET collected daily	Kg CO_2 eq	BEP for scenario B (days)	BEP: B - A (days)	BEP for scenario C (days)	BEP: C - A (days)
5%	0,53	-0,8925	4009,0	76,2	4923,2	990,5
10%	1,05	-1,785	2004,5	38,1	2461,6	495,2
15%	1,58	-2,6775	1336,3	25,4	1641,1	330,2
20%	2,10	-3,57	1002,2	19,0	1230,8	247,6
25%	2,63	-4,4625	801,8	15,2	984,6	198,1
30%	3,15	-5,355	668,2	12,7	820,5	165,1
35%	3,68	-6,2475	572,7	10,9	703,3	141,5
40%	4,20	-7,14	501,1	9,5	615,4	123,8
45%	4,73	-8,0325	445,4	8,5	547,0	110,1
50%	5,25	-8,925	400,9	7,6	492,3	99,0
55%	5,78	-9,8175	364,5	6,9	447,6	90,0
60%	6,30	-10,71	334,1	6,3	410,3	82,5
65%	6,83	-11,6025	308,4	5,9	378,7	76,2
70%	7,35	-12,495	286,4	5,4	351,7	70,7
75%	7,88	-13,3875	267,3	5,1	328,2	66,0
80%	8,40	-14,28	250,6	4,8	307,7	61,9
85%	8,93	-15,1725	235,8	4,5	289,6	58,3
90%	9,45	-16,065	222,7	4,2	273,5	55,0
95%	9,96	-16,9575	211,0	4,0	259,1	52,1
100%	10,50	-17,85	200,4	3,8	246,2	49,5

Table 6. *PET collection rate and saving of CO2.*

Actually, many countries still don't achieve the EU objectives in waste management and !!br0ken!! If we consider to introduce the use of the BURBA system in one of these countries where the PET separation percentage is very low (as an example, at the present time Malta is less than 20%) the introduction of the IWACs and the adoption of PAYT schemes could cause a dramatic change in the citizens attitude and behaviour with a significant increase of the recovered PET from MSW.

In such a situation in which the PET separation rate is 20%, the use of the BURBA system could improve it up to 30%.

Then to pay the CO2 delta of the Environmental debt between a normal HDPE waste container system and the other schemes with BURBA's IWACs (i.e. the additional environmental debt due to the electronics, battery and other components that are not present in a normal HDPE container), are needed:

- 13 days (with one IWAC dedicated to PET collection and 12 standard HDPE containers)
- 165 days with 13 IWACs

If we consider, in the same situation the time needed to pay back the CO2 environmental debt of the entire group of 13 IWACs, we will have paid back the CO2 debt in 820 days, this with just the benefits of the one IWAC dedicated to PET collection. This time comes down to 668 days if we choose a mixed system composed by one IWAC and 12 std containers.

All the payback times are compatible with the average life of a waste container, either IWAC or standard HDPE.

If we consider another scenario in which the recycling rate for PET is already high, (such as 60%, in countries like Germany or Norway) we could postulate that the increase due to the introduction to the BURBA could be as low as 5%.

In such scenario it will take only 6 days to pay the CO2 delta environmental debt between a normal HDPE waste container system and a system with one IWAC dedicated to PET collection and 12 standard HDPE containers.

If we compare the delta environmental debt between standard waste containers and a system composed only by IWACs, the break-even point is reached in 76 days.

6. Current Status and conclusions

The BURBA system is currently ready to be industrialised.

The whole system electronics is contained in a box that can be used to retrofit the existing usual waste containers, so far minimising the cost of the adoption by municipalities, communities, waste management companies.

We performed the LCA of the intelligent waste bin for municipal solid waste collection. The quantified environmental impacts were then compared to those of a standard HDPE waste container.

The BURBA intelligent waste container has been devised to support PAYT schemes and to improve service to the citizens with the ultimate goal of supporting the progress toward the achievement of the European Directives targets for waste separation and recycling.

One relevant issue for the introduction of new "green" technology, is to assess if it is really green, i.e. if the claimed environmental benefits, such as "improved separation and collection of recyclable waste" are counterbalancing its environmental impacts.

The present study answered to this critical question presenting the case of the intelligent waste container for the improved separation of PET bottles. In such a case, under the conservative hypothesis, supported by the literature, of an increase of 5% of PET sorting from 60 to 65 %, by the citizens thanks to service amelioration, support to PAYT schemes, perceived financial benefit, container novelty, information feedback, resulted that the exceeding environmental CO2 debt of the intelligent waste container with respect to that of a standard HDPE container would be paid back in few days or weeks depending on the relative number of HDOE container and IWAC employed.

To our knowledge this is the first LCA study of sensorized waste containers, and the first to ascertain that its adoption would provide quantifiable environmental benefits.

The BURBA system is much more advanced than its market competitors.

Also it appears to be the only advanced waste container that has been assessed through a Life cycle assessment study with data publicly available. This LCA shows how the system is paid back, in terms of environmental impacts, in very short time thanks to its benefit. Furthermore BURBA estimated market price is very competitive.

Producer	Name	Web platform	RFID	Weighing	Volume measurement	GPS	overall
BURBA consortium	BURBA	Y	Y	Y	Y	Y	6/6
Pottinger	Multipress - eco	Y	Y	Y	N	N	3/6
Big belly solar	Big belly	Y	N	N	Y	N	2/6
AMCS	IAW	Y	Y	Y	N	Y	4/6
Springtime	Expand recycle	N	Y	N	N	Y	2/6
MOBA	MAWIS	Y	Y	Y	N	Y	4/6

Table 7. *Comparison between BURBA and its competitors.*

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Dr. Paolo Barattini, MD PhD*, worked in many ESA and EU projects including FP7 Theraedge, FP7 LOCOBOT, FP7 BURBA, FP7 MARIABOX, ESA ISS-MPLM study, ESA HEWS project; ESA MARES Project, ESA PEMS I project. He also worked as a consultant and taught courses in the field of ISO 2700, 2000, 9000 ; He participates in ISO working groups in assistive and service robotics. Previously member of the Italian Ergonomics Association. His experience includes design and enabling of new services through software implementations, GUI and HMI/HRI interaction, complex automated devices, Ergonomics,c ircadian rhythms, biomechanics, training, design of software and hardware for biomedical services and applications, software testing.*

Animals and Environment monitoring

Animals and Environment monitoring using cooperating objects platform

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ABSTRACT: *Efficient deployment has been identified as one of the main problems for the acceptance of new technologies based on Cooperating Objects (COs). The goal of the PLANET project is to provide an integrated planning and maintenance platform that enables the deployment, operation and maintenance of heterogeneous networked COs in an efficient way. The project particularly emphasizes the capability of the platform to support deployment and operation strategies for large-scale systems composed of unmanned ground and aerial vehicles cooperating with wireless sensors and actuators. In this article, we elaborate the solution of the PLANET integrated framework and its supporting techniques.*

KEY WORDS: *Cooperating objects, Deployment, Sensor Networks, Autonomous Unmanned aerial/ground vehicles, Data collection, Integrated framework*

1. Introduction

The continuous miniaturization of everyday devices, as well as the convergence of communication, computing and control has been considered by many the future of information and communication technology (Andersson et al., 2008) (Bicket et al., 2005) (Deng et al., 2004). Such convergence will provide the ability to build large-scale, heterogeneous, pervasive, networked systems that can be deeply embedded in the physical world. The underlying technology that serves as the basis for this field is Cooperating Objects (COs), which do not only have the capability to sense, but also to act upon the environment (Abdelzaher et al. 2004). In the general case, the deployment of very large-scale/ complex systems consists of a series of heterogeneous devices such as unmanned aerial or ground vehicles (UAVs or UGVs), wireless sensor or actuator networks that work together in a seamless fashion and integrate with the pre-existing infrastructure in a transparent way.

For this reason, a solution applicable to a wide variety of scenarios requires the development of new distributed architectures and integration platforms that have the following characteristics:

- Are able to *adapt* to the changing conditions of the network and the application itself in order to choose an *optimal* solution that is guaranteed to work under the given conditions.
- Support *security* natively (and not just as an add-on) regarding the algorithms used in the deployment as well as the planning and maintenance of the network.
- Are able to cope with *heterogeneity* from the point of view of devices as well as conditions in the network such as different mobility patterns or activities in the network.
- Are able to cope with *static devices* integrated in the infrastructure, as well as *mobile devices* used for the most varied purposes.
- Are able to support the planning, deployment and maintenance of *real-world applications.*

The main objective of the PLANET project, FP7-ICT-2009-5, (PLANET 2000), is therefore the design, development and validation of an integrated platform to enable the deployment, operation and maintenance of large-scale/complex systems of heterogeneous networked Cooperating Objects, including Wireless Sensor and Actuator Networks and mobile objects. The platform aims to support optimal and adaptive deployment and operation by means of autonomous UAVs and UGVs, networked with static nodes. The platform has been validated in two complementary scenarios: the monitoring of the Doñana Biological Reserve with very high ecological value and very sensitive to the impact of pollution, and the highly automated airfield scenario in which security plays an important role and where wireless communication and cooperative techniques pose significant challenges. The following sections details the PLANET integrated solution as well as underlying techniques to achieve the above objectives.

2. PLANET Integrated Framework

Figure 2 illustrates an iterative workflow of our approach that supports the characteristics and challenges for automating CO deployment and operation as discussed previously.

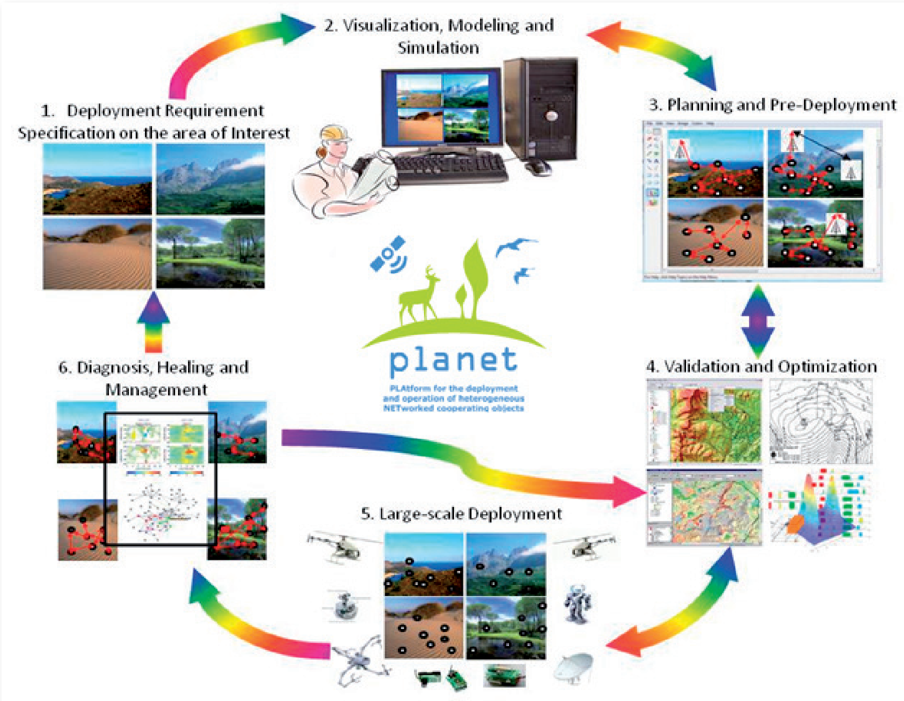

Figure 1. *The PLANET Approach*

As shown in the figure, the first step for CO network deployment is to allow the user to specify their requirement and deployment specification. Such user input is then processed by PLANET in order to simulate the deployment environments and to visualize the deployment process (step 2 in Figure 2). With the PLANET planning tool, the deployment positions and network topology can be decided based on the simulated environment (step 3). The application correctness is then validated with the planned deployment locations and the application performance is evaluated and optimized (step 4). When the evaluation result indicates that the user requirement is met, PLANET proceeds with the deployment operation, particularly with autonomous UAVs or UGVs if the deployment area is hard to approach or inaccessible (step 5). During the deployment operation, the UAVs or UGVs report to PLANET the deployment progress including the actual deployment locations and vehicle status such as battery life and moving speeds, etc. PLANET then exams the current status and adapts to the actual deployment situation with the real environment in order to ensure that the deployment can fulfil the user requirements. Once the CO deployment has been successfully deployed, PLANET monitors the health of the deployed networked COs. It also performs network management and recovers the network if some failure has been detected using a light but efficient weight monitoring mechanism (step 6).

It is worth noting that the above work flow can be automated in a seamless manner with the integrated PLANET framework via the communication middleware developed in the PLANET Project. We elaborate in the next section the techniques developed in PLANET to carry out the two target scenarios, the DBR wildlife monitoring and the automated airfield, with the integrated framework.

3. PLANET Techniques

To achieve the vision of PLANET, several techniques have been developed in PLANET for many aspects including: CO communication, deployment planning and simulation, CO deployment/retrieval, data collection and visualization. We particularly address the PLANET's capability of using mobile vehicles for autonomous deployment and data collection. The following subsections detail these supporting techniques.

3.1. PLANET Communication Middleware and Secure Communication

The key to automate the CO deployment and operation in PLANET is to have an efficient and scalable communication scheme that links the tasks of the integrated framework at different steps in the work flow.

The PLANET middleware is developed to serve this purpose. The middleware takes a layer approach and follows the publish-subscribe model, which allows all participants to focus on the interested messages. Each CO interacts with others by defining messages in the format of the Google Protocol Buffers. The middleware handles these messages internally and delivers the messages via underlying communication mechanism (currently using RTI DDS, Data Distribution Service) (RTIDDS 2007). The middleware includes message handling, CO monitoring and management layers that ensure the CO system correctness and secure communication in a non-intrusive manner. In the prototype of the integrated system, all PLANET framework components and functional COs, including UAVs, UGVs, sensors, data collection units, are "planetized" to perform their tasks, as shown in Figure 2.

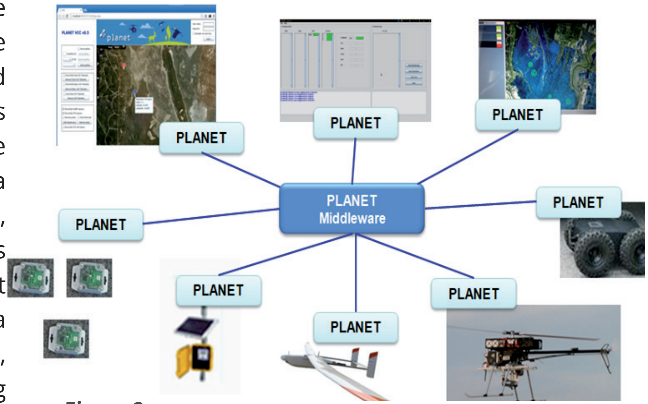

Figure 2.
The PLANET Middleware with Integrated COs

3.2. Deployment Planning, Simulation and Visualization

To provide an optimized deployment strategy based on the user requirement, we developed a planning tool that can be flexibly augmented with user-defined environment models and deployment optimization algorithms. We have designed and implemented a set of algorithms for determining the deployment locations of the static COs and the route of the mobile COs. The PLANET planning tool generates deployment plans and interacts with the simulation tools via the middleware to evaluate the generated deployment plans. All the planning/simulation progress, as well as the later deployment and operation status, can be visualized using the PLANET Visualization and Control Center (VCC). Figure 3 illustrates the architecture of the PLANET planning tool and some example views that are displayed by the PLANET VCC.

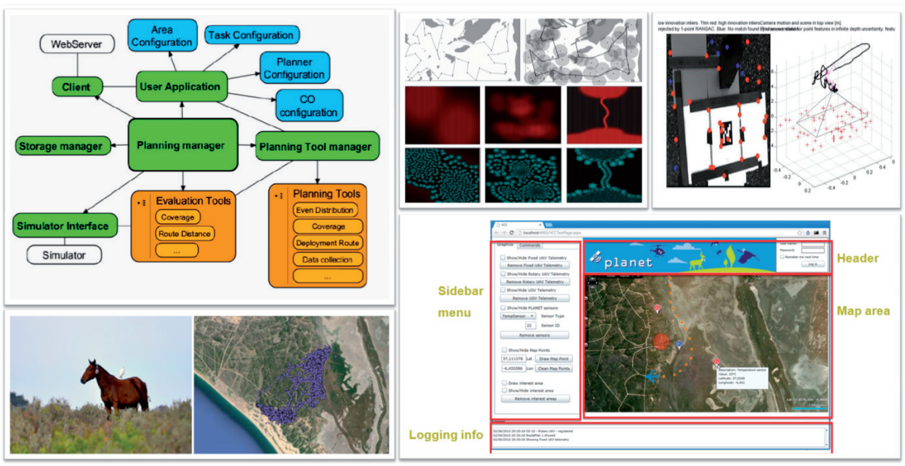

Figure 3. *PLANET Deployment Planning and Simulation Tools*

3.3. Cooperating Object Deployment and Retrieval

With the generated deployment, the COs are deployed accordingly by either human engineers or autonomous UAVs or UGVs in PLANET. The deployment operations carried out for the two PLANET application scenarios cover different deployment techniques (as illustrated in Figure 4). For the horse monitoring in DBR, a set of sensor-integrated collars is mounted on the about 40 horses and a set of ground stations is deployed to collect the horse sensor data. For environmental monitoring, several UAV platforms (air planes and helicopters) have been equipped with deployment device to carry and deploy the sensor nodes at the specified locations. Currently, we have successfully performed the deployment tasks with these UAV platforms to deploy environmental sensors (temperature, humidity, PH, CO2, etc) to measure the physical parameters of the monitored area and the water pollution level.

In addition to the deployment operations, we have developed an innovative technique for CO retrieval. The helicopter platform is augmented with a retrieval device and is able to pick up a small-scale ground vehicle.

Figure 4. *PLANET CO Deployment Techniques Using UAVs and UGVs*

3.4. Data Collection

In PLANET, a variety of data is collected using a wide range of techniques (as shown in Figure 5). For the mobile horse data and static ground sensors, the static data collection stations are installed to collect the sensor data from the sensors that are within the radio coverage. For collecting the data from the sensors that are remote to the ground stations, aerial and ground vehicles are given with sensor locations and can autonomously drive themselves to perform data collection. To automate the data deliver process, a UGV platform is integrated with a data collection station that runs the data collection and delivery service and delivers the data via the PLANET middleware. Additionally, the airplane is equipped with high resolution camera to perform image mosaicing to acquire the landscape overview of inaccessible monitored area.

Other than the physical environmental sensor data, PLANET also covers the techniques to use the UAV to perform water sampling by developing a water-pump device, which is integrated with the helicopter platform.

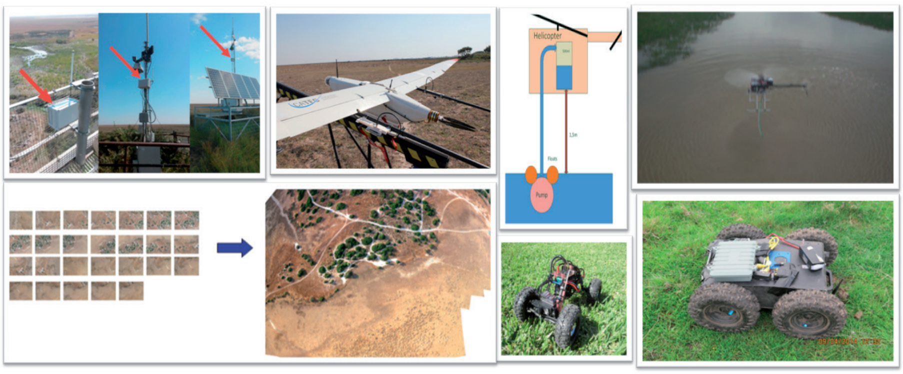

Figure 5. *PLANET Data Collection with UAVs and UGVs*

4. Conclusion

The development of the PLANET project is at its last stage. The techniques regarding CO deployment and operation described in this article have been mostly completed and tested with the experiments conducted in real deployment environment. The validation experiments cover the all different tasks to be performed in the PLANET workflow discussed in Section 2. The experiment results have demonstrated the capability of the PLANET integrated framework to achieve the project objectives, i.e., adaptivity, scalability, autonomous deployment and data collection.

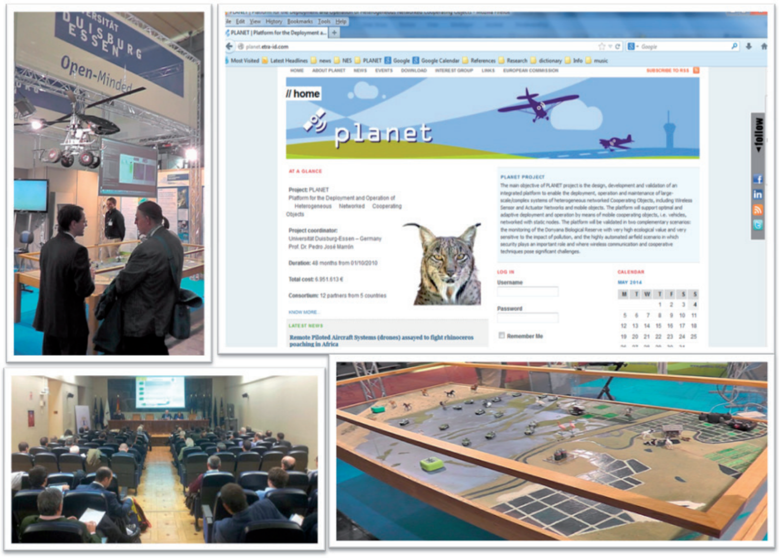

Figure 6. *PLANET in Public*

To develop such a complex system requires various supporting techniques in different aspects. The PLANET consortium has successfully associated different professional teams with experts from different hardware/software backgrounds including sensing devices, aerial and ground robots, CO application programming, image mosaicing, and algorithm implementation for CO control, network monitoring, deployment planning, security, simulation, etc. As the result, many innovative techniques have been designed and developed.

During the last two years, the PLANET framework has been introduced publicly (see Figure 6) including news, radios, workshops, conferences and the exhibitions such as CEBIT, in which PLANET attracted a lot of visitors. Several pending patterns are in progress regarding the aerial vehicles integrated with the devices that are capable of interacting with the physical environment. By the end of the project (the end of 2014), we expect all the validation experiments will be performed, and the PLANET techniques can be more mature for real-life Cooperating Object deployment.

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Smart Manufacturing and Smart Agriculture

Practical IoT deployment on Smart Manufacturing and Smart Agriculture based on an Open Source Platform

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ABSTRACT: *This chapter introduces successful deployments of the OpenIoT platform in the manufacturing and farming domains by means of smart applications. OpenIoT is an award-winner open source platform for building and deployment semantically interoperable IoT deployments in the cloud. It allows the streaming and semantic unification of diverse data streams in the cloud, while at the same time offering visual tools for developing and deploying applications. The presentation of the deployments aims at providing application examples (case studies), which could be extended and replicated in the same or even other domains.*
The smart manufacturing application illustrates the streaming of numerous manufacturing plant sensors within a cloud infrastructure, along with their combination and use in order to dynamically define and calculate indicators of manufacturing performance. The merit of this approach is that it allows plant managers to dynamically compose and exploit the various sensors, rather than relying on a closed limited set of predefined indicators.
The smart agriculture application illustrates the large-scale collection and processing of sensor-derived information for optimizing crop management. To this end, appropriate reports are created and offered to bio-plant experts, which accordingly can interpret the measure for crop optimization.

KEY WORDS: *IoT, Cloud Computing, OpenIoT, Semantic Interoperability, Manufacturing, Agriculture*

1. Introduction

We are recently witnessing the convergence of two of the most prominent pillars of the Future Internet, namely Cloud computing [1] and Internet-of-Things [2]. This convergence is motivated by the fact that IoT applications can greatly benefit from the streaming and processing of IoT data in the cloud. Indeed, IoT applications produce large volumes of data with different velocities and formats, which could take advantage of the scalability, capacity, elasticity and performance of cloud computing infrastructures. During recent years we have therefore witnessed the proliferation of a large number of platforms that realize the IoT/cloud convergence, including platforms developed in research initiatives (e.g., [3-4]) and enterprises platforms (such as Xively.com, Thingspeak.com and sensorcloud.com). The latter enterprise platforms are usually characterized as public IoT clouds (since they are publicly accessible) and used to support several enterprise applications. Recently, we have also witnessed the emergence of open source IoT cloud platforms[5].

One of the main limitations of all the platforms outlined above is the lack of semantic interoperability between the different IoT applications and deployments that are built and supported by them. This lack of interoperability is reflected on the different ways and vocabularies used to describe physical things (objects), their location, their capabilities, as well as virtual objects (i.e. higher level abstractions combining other physical or virtual objects). Moreover, the various IoT deployments tends to model differently the physics and mathematics, which are typically associated of sensing, observational and actuating tasks. Motivated by this lack of semantic interoperability in IoT/cloud platforms, the OpenIoT project has during the last two years introduced and developed an open source IoT/cloud platform for semantically interoperable deployments [6].

The OpenIoT platform uses the W3C Semantic Sensor Networks (SSN) ontology [7] as a standards-based model for the semantic unification of diverse IoT systems and data streams. It also blends cloud-computing concepts (e.g., the on-demand utility-based pay-as-you-go access to resource) with sensing/IoT concepts, thereby providing support for on-demand access to available IoT resources in the cloud. In this way, OpenIoT enables a novel utility-based model for IoT such as «Sensing-as-a-Service» applications. This model is empowered by a range of visual tools, which come with the OpenIoT platform in order to facilitate application design, development and deployment. These tools make OpenIoT appealing for several IoT applications, including both large-scale applications (where semantic interoperability is an essential requirement) and smaller scale applications (which can benefit from rapid on-demand application design and deployment). Note that OpenIoT encompasses and extends popular open source projects in the IoT and WSN (Wireless Sensor Networks) area such as the Global Sensor Networks (GSN) middleware [8], which enables the streaming and integration of diverse sensors and sensor networks based on nearly zero programming. OpenIoT extends GSN's virtual sensor concept towards a semantically rich virtual sensor model, which enables the deployment and use of data streams in the cloud independently from their originating physical devices or data source.

On the basis of its above-listed novel features, OpenIoT has been recently awarded/voted for the Black Duck open source rookie aware for 2013 [9], which classified the project as one of the top ten open source projects of the past year. This award has recently given rise to the take up of the project in practical deployments. Currently several organizations (notably OpenIoT partners) have successfully built and deployed applications based on OpenIoT, while other organizations and projects and evaluating the platform for their own purposes. The purpose of this chapter is to illustrate two practical deployments of the OpenIoT platform in the manufacturing and agriculture domains, as successful examples of the use of the OpenIoT infrastructure. These examples can serve as guide for IoT developers, solution providers and integrators wishing to use OpenIoT for developing/deploying IoT/cloud applications in the same or even other domains. In order to facilitate the presentation of the successful deployment, we first introduce briefly the structure, main characteristics and features of the OpenIoT platform. The structure of the chapter is as follows: Section 2 provides an overview of the OpenIoT platform and tools. Section 3 is devoted to the description of the deployment in the manufacturing domain, which Section 4 focuses on the description of the successful deployment in the smart agriculture domain. Finally, Section 5 concludes the paper.

2. OpenIoT Platform Overview

2.1. Modules and Building Blocks

The OpenIoT open source platform consists of the following building blocks (see Figure 1):

- **The Sensor Middleware (Extended Global Sensor Network, X-GSN)** collects filters and combines data streams from virtual sensors or physical devices. It acts as a hub between the OpenIoT platform and the physical world. The Sensor Middleware is deployed on the basis of one or more distributed instances (nodes), which may belong to different administrative entities. The prototype implementation of the OpenIoT platform uses the GSN sensor middleware that has been extended and called X-GSN (Extended GSN).
- **The Cloud Data Storage (Linked Stream Middleware Light, LSM-Light)** enables the storage of data streams stemming from the sensor middleware thereby acting as a cloud database. The cloud infrastructure stores also the metadata required for the operation of the OpenIoT platforms (functional data). In addition to data streams and metadata, the cloud could also host computational (software) components of the OpenIoT platform (i.e. Schedules and SD&UM) in order to benefit from the elasticity, scalability and performance characteristics of the cloud. The prototype implementation of the OpenIoT platform uses the LSM Middleware, which has been re-designed with push-pull data functionality and cloud interfaces for enabling additional cloud-based streaming processing. Note that OpenIoT provides flexibility in terms of the cloud infrastructure where the data will be streamed and persisted. Specifically, a solution integrator may opt for integrating a public cloud (e.g., Amazon EC2) or even a private cloud solution according to its requirements.
- **The Scheduler** processes all the requests for on-demand deployment of services and ensures their proper access to the resources (e.g. data streams) that they require. This component undertakes the following tasks: it discovers the sensors and the associated data streams that can contribute to service setup; it manages a service and selects/enables the resources involved in service provision.
- **The Service Delivery & Utility Manager performs a dual role**. On the one hand, it combines the data streams as indicated by service workflows within the OpenIoT system in order to deliver the requested service (with the help of the SPARQL query provided by the Scheduler). To this end, this component makes use of the service description and resources identified and reserved by the Scheduler component. On the other hand, this component acts as a service metering facility that keeps track of utility metrics for each individual service. This metering functionality will be accordingly used to drive functionalities such as accounting, billing and utility-driven resource optimization. Such functionalities are essential in the scope of a utility (pay-as-you-go) computing paradigm, such as the one promoted by OpenIoT.
- **The Request Definition component** enables on-the-fly specification of service requests to the OpenIoT platform. It comprises a set of services for specifying and formulating such requests, while also submitting them to the Global Scheduler. This component may be accompanied by a GUI (Graphical User Interface).
- **The Request Presentation component**, which is in charge of the visualization of the outputs of a service that is provided within the OpenIoT platform. This component selects mash-ups from an appropriate library in order to facilitate service presentation. It is expected that service integrators implementing/integrating solutions with the OpenIoT platform are likely to enhance or even override the functionality of this component on the basis of a GUI pertaining to their solution.
- **The Configuration and Monitoring component**, which enables management and configuration of functionalities over the sensors and the (OpenIoT) services that are deployed within the OpenIoT platform. It is also supported by a GUI.

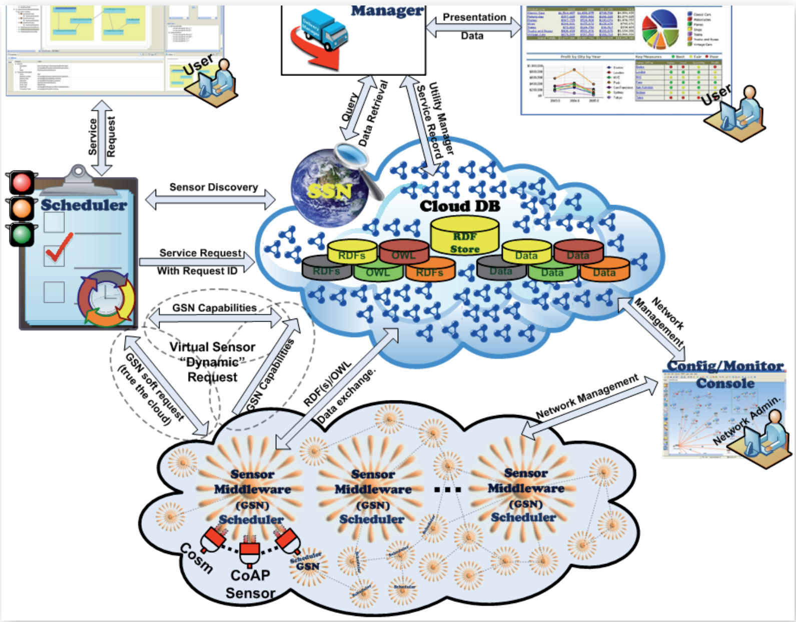

Figure 1. OpenIoT Platform Architecture and Main Elements

2.2. Data Flow

On the basis of the architecture illustrated above the data flow within OpenIoT systems is as follows:

- X-GSN nodes are "announcing" the available virtual sensors to the Directory Service and start to publish their data in SSN compliant RDF (Resource Description Format) format based on each X-GSN local configuration.
- A User requests from the Scheduler all the available sensor types that satisfy specific attributes (coordinates and radius) by using the Request Definition UI from the Directory Service. The request is sent to the Scheduler service.
- The Scheduler executes a combination of queries (SPARQL) to fulfil the previously user specified query provided by the previous step.
- The Directory Service retrieves the data and replies back to the Scheduler with the available sensor types.
- The reply is forwarded to the Request Definition UI from the Scheduler and the retrieved information is provided to the User.
- The User, with the help of Request Definition UI, defines the request by implementing rules, provided by the tool, over the reported sensor types. This information, along with execution and service presentation preferences is then pushed to the Scheduler.
- The Scheduler analyses the received information and sends the request to the Directory Service.
- After having configured the request, the User is able to use the Request Presentation UI for visualising a registered Service's data.
- With the help of SD&UM the Request Presentation retrieves all the registered applications/services related to a specific User.
- Having selected a specific service, the User requests to retrieve the results related to it. This is done by submitting a "pollForReport" from the Request Presentation to the SD&UM having the applicationID as input.
- The SD&UM requests (SD&UM's "getService") from the Directory Service to retrieve all related information for the specific Service.
- The Directory Service provides this information to the SD&UM.
- The SD&UM analyses the retrieved information and forwards the included SPARQL script (which has been created by the Request Definition UI and stored by the Scheduler) to the Directory Service SPARQL interface.
- The result is sent from the Directory Service to the SD&UM, in a SparqlResultsDoc format. Then the SD&UM forwards it to the Request Presentation that also includes information on how these data should be presented.

This typical data flow forms the basis for application development, deployment and presentation based on the OpenIoT platform.

3. OpenIoT in Intelligent Manufacturing

3.1. Functional Overview

Nowadays plant managers install a large number of sensors in order to monitor their production processes. In particular, mid-sized plants are likely to comprise many hundreds of sensors of different types and for various purposes. These sensors generate a great volume of information, while they are associated with an always-increasing rate of information. As a result significant information can be derived from these sensors regarding manufacturing performance (on the basis of appropriate KPIs (Key Performance Indicators)). In order to extract this information there is a need for efficient solutions for capturing, storing and processing sensor data is required. The monitoring of manufacturing performance could therefore greatly benefit from a system that enables plant managers to dynamically select the information they want, through selecting information (in almost real-time) and using it to constructing KPIs dynamically. Such as solution would allow the dynamic construction of KPIs, beyond the fixed sets of KPIs that state-of-the-art manufacturing performance systems provide. The on-demand service composition capabilities of OpenIoT provide the means for dynamically selecting sensor information, as well as for structuring this information on KPIs.

The construction and monitoring of KPIs based on the OpenIoT system has been realized by manufacturing solutions integrator SENSAP S.A (www.sensap.eu) for the paper and packaging industry. In particular, SENSAP has developed a set of applications for monitoring and tracing the flow of materials in the scope of production processes. The applications enable packaging manufacturers to dynamically define and visualize Key Performance Indicators (KPIs) associated with their manufacturing processes, by leveraging the semantic capabilities of the OpenIoT platform, and in particular its capabilities for dynamic discovery of sensors and of sensor data. The KPIs are defined and computed on the basis of a wide range of data streams, which are: (A) Collected by physical sensors residing in the shop floor, (B) Transformed into higher-level virtual sensors that comprise business events compliant to the data model of the EPC-IS standard [10], (C) Conveyed to the X-GSN sensor middleware, which ensures the semantic annotation of the data streams of the virtual sensors and their subsequent publication to the OpenIoT cloud.

While a large number of KPIs can be devised, the deployment focuses on three very common operations for the paper and packaging industry, namely printing, die cutting and gluing/folding. The above operations are executed sequentially and process each unit (of packages) produced. A set of (virtual) sensor streams are collected and published to the OpenIoT cloud. The virtual sensors concern the calculation of:

- Operation rate for a specific process (measured in units/hour).
- Utilization metrics of the machines involved in the operation.
- Percentage of an operation that has been completed (in terms of the time required to complete the operation).
- Operation rate for the total process (measured in units/hour).
- Defect rates per operation and/or per process
- State of the individual operations and the whole process (idle, stopped, in setup, in production).
- Production rate per product type.
- Defect rate per material type.

Once the information for these parameters is published in the OpenIoT cloud, manufacturers are able to dynamically discover and synthesise information from the above virtual sensors with a view to calculating (on-the-fly) KPIs (e.g., operation rates, utilization rates) for specific processes, while also being able to combine these metrics in order to calculate the parameters for composite (or even all) processes. Interesting opportunities arise in case the above virtual sensors are published to the OpenIoT cloud, not from just one, but rather from many (packaging/printing) manufacturers running the printing, die-cutting and gluing/folding processes. Overall, the semantic and dynamic discovery capabilities of the OpenIoT infrastructure are able to deliver on the fly manufacturing intelligence to end-users for monitoring, maintenance and planning purposes.

3.2. Implementation and Deployment

The implementation of the manufacturing performance applications outlined above, involves:

- **Sensors**: A range of physical sensors, which are used to measure rates, quality information and traceability information associated with the printing, die cutting and gluing/folding processes.
- **Traceability Kiosk and S-BOX Products of SENSAP**: SENSAP's ITK product is used to collect the data from the sensors and to process them in order to produce a set of virtual sensors (as data streams). The processing is performed by SENSAP's S-BOX product, which transforms the data into EPC-IS events comprising business context associated with the manufacturing processes (cutting, printing, folding etc.).
- **X-GSN middleware**: EPC-IS data streams (produced within S-BOX) are interfaced to the X-GSN sensor middleware. In-line with the OpenIoT architecture, the X-GSN middleware annotates the data streams in a way that makes them compliant to the OpenIoT ontology (which is an enhanced version of the W3C SSN ontology).
- **OpenIoT LSM Cloud Infrastructure**: The information (KPIs) associated with the manufacturing processes is streamed from the X-GSN middleware to the OpenIoT LSM cloud. This streaming process is a feature of the OpenIoT architecture.
- **KPIs Composition and Visualization Infrastructure**: Using the OpenIoT's request definition tool, one can dynamically define IoT services which (dynamically) calculate KPIs associated with manufacturing processes. The calculation of the KPIs is based on data available in the LSM cloud.

In following paragraphs we provide more detailed and specific information about each one of the above components.

3.2.1 Physical Sensors

The implementation of the manufacturing scenario hinges on the collection of information about the manufacturing process from the shop floor. This collection is empowered by the following physical sensors:

- Optical sensors for performance sensing, which measures rate and quantity of produced items.
- Vision (image) sensors for quality control, which perform quality inspection of the produced items (e.g. checking colour patterns for detecting printing errors).
- RFID/barcode scanner for traceability, i.e. sensors which collects traceability data (such as LOT numbers).

The sensors collect information about the materials used and the machines utilized in the scope of the execution of a production order. Additional information about materials and utilization can be collected based on optical diffusion sensors, weight sensors and temperature sensors. These physical sensors are part of SENSAP's ITK solution, since they are integral elements of the ITK module.

3.2.2 ITK and S-BOX Products

The physical sensors outlined above are attached to the SENSAP™ INTEGRA ITK automation module, which has been designed and manufactured with an emphasis on the needs of the Printing and Carton-Converting industry. The ITK collects and processes information from the sensors towards quality and performance inspection, traceability data acquisition, as well as monitoring of material-consumption and resource-utilization. It encompasses all critical manufacturing operations, and auxiliary activities ranging from lamination and folio-sheeting to gluing/folding and shipping. Each ITK unit is directly connected on Printing, Die-Cutting, and Gluing/Folding machines, with a view to acquire and processes live data regarding machine performance, product quality, and raw-material consumption. An overview of an ITK unit is illustrated in Figure 2.

Figure 2: *Integra Traceability Kiosk*

An ITK unit is attached to each one of the machines performing the printing, die-cutting and gluing/folding operations of the scenario. In technical terms, the ITK collects sensors information and generates appropriate EPC-IS (Electronic Product Code Information Sharing) events i.e. events (information units) compliant to the EPC-IS standard. EPC-IS events comprise business context, associated with the printing operations (e.g., such as the business process executed, the LOT number of the product, state changes to the product) and therefore have much richer semantics than the raw sensor data. The conversion of physical sensors data to EPC-IS compliant virtual sensors is controlled through a Graphical environment called PCS (Performance Control System). The PCS allows manufacturers and/or integrators to define the EPC-IS virtual sensors on the basis of combining data from the physical sensors attached to the ITK. This offers significant flexibility in the definition and configuration of EPC-IS events. These events are structured as virtual sensors, which are providing information to the OpenIoT cloud.

Figure 3: *Performance Control System (Collects Information from Physical Sensors)*

3.2.3 X-GSN and OpenIoT Linked Sensor Middleware (LSM)

The X-GSN middleware (i.e. the enhanced version of the GSN middleware that is contained in the OpenIoT platform) is used to stream (EPC-IS) virtual sensors to the OpenIoT cloud. To this end, the virtual sensors have been described/annotated as GSN Virtual Sensors (i.e. based on the XML file of the Virtual Sensor) (see Table 1 and Table 2 for two examples of virtual sensor descriptions). Accordingly, the X-GSN middleware converts the data to an OpenIoT compliant (i.e. compliant to the OpenIoT ontology) RDF format. This data is published to the OpenIoT cloud through the interface of the X-GSN to the LSM middleware. The integration with the OpenIoT platform involves the following steps:

- Interfacing of the available X-GSN infrastructure (comprising the EPC-IS events as virtual sensors) to the OpenIoT LSM cloud. This enables the publication of manufacturing performance and materials flow traceability data in the cloud.
- Deployment of the models/workflows created with the request presentation tool, over the OpenIoT infrastructure. This leads to visualization of operational rates and utilization rates to appropriate OpenIoT mash-ups.

The integrated system is deployed as add-on to paper and packaging manufacturers, notably manufacturers that have already adopted the ITK solution to manufacturing resources traceability. The deployment of the solution across multiple manufacturers could enable the development of added value applications for the calculation and visualization of crowd-sourced KPIs, such as the defect rates of a given machine across multiple plants, or the average performance of a given operation. This is a result of the semantic interoperability features of the OpenIoT infrastructure, which enables the construction and exploitation of collective intelligence based on numerous geographically and administratively dispersed sensor sources.

3.3. Outlook on Generalization and Wider Deployment

The successful OpenIoT deployment on the manufacturing sector provides insights on how the open source platform could serve as a basis for analogous deployments in the broader area of manufacturing intelligence. Indeed, OpenIoT makes it very easy to integrate diverse sensor sources in the cloud, while ensuring their semantic interoperability. In particular the OpenIoT tools make it easy for a solution developer to integrate a given sensor stream with a minimal effort (1-2 man days maximum). At the same time, the OpenIoT scheduler and semantic web infrastructure (empowered by the representation of sensors according to the W3C SSN model) enable the querying of large-scale distributed systems as simple as executing queries over a local database (based on the SPARQL language). Therefore, the infrastructure outlined above could be generalized for a wider class of manufacturing intelligence applications that rely on the dynamic calculation and use of KPIs associated with the one or more sensor streams stemming from manufacturing plants.

4. OpenIoT in Smart Agriculture

4.1. Functional Overview

The OpenIoT deployment in Smart Agriculture is linked to the Phenonet project of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) research organization in Australia. 'Phenonet' describes the network of wireless sensor nodes collecting information over a field of experimental crops. The term "Phenomics" describes the study of how the genetic makeup of an organism determines its appearance, function, growth and performance. Plant phenomics is a cross-disciplinary approach, studying the connection from cell to leaf to whole plant and from crop to canopy [11].

Analysing the size, growth and performance of plants in a greenhouse or field site can be time-consuming and laborious. More specifically, when a field site is located in a remote area, it becomes quite expensive to send people out to the field. The ability to collect this information from remote locations and send it back to the laboratory in real time is an invaluable tool for plant scientists [12]. CSIRO has developed smart wireless sensors nodes that work autonomously and independently cooperating with each other to set up an ad hoc network to record environmental conditions and wirelessly transfer data to a data store.

The specific deployment is linked to a certain agriculture research experiment. The purpose of the experiment is to evaluate the effect of sheep grazing on crop re-growth by looking at root activity, water use, crop growth rate, and crop yield. The information about crop growth obtained in real time can effectively help the researchers to provide estimates on the potential yield of a variety. The experiment tries to compare trade-offs between grazed and un-grazed setup for a particular variety of crop. This experiment is supposed to last for 9 months. The animals come in the first 6 months and after that they are removed from the site. To compute the root activity and water usage, a soil moisture sensor is deployed. Sensors at one depth level don't tell the entire story. Multiple depths are needed in order to observe behaviour of the root system and the water available to the crop at any particular time. The target functionalities include:

- **Efficiently and effectively manage the water resource**: The soil profile information could be used in a farming production system as follows. If there is not enough water left in the soil profile, the farmer may decide to move the livestock's into the site (crop farm). The movement of livestock into the site will cause the water usage to be reduced as livestock feed on the leaves. This will delay the use of water use until the vital grain filling period. When soil moisture is high, the farmer may decide to move the livestock off the site so that the plants can consume the water effectively and produce higher yields.
- **Efficiently and effectively administer the timing of using fertilizers**: The farmer may also use the soil profile information obtained in real time to arrive at a decision on when to apply nitrogen to the soil to aid crop growth. Nitrogen is applied generally when soil moisture is high, so it supports the growth of the crop, otherwise nitrogen is wasted.
- **Dual Purpose Cropping System**: Increase crop yield by efficiently and effectively utilising the resources (water and fertilizer) while also allowing livestock to feed on healthy crop leaves enriching live stock growth.

The above setup is not only for experimenting but farmers benefit from it by using the data to plan nitrogen fertilizer, timing of moving animals (animals/live stock eat leaves of the plants, which is, but eating the flower which yields the grains is not good) in and out before they start eating the reproductive part of the plants (called the flower) and planning water resources. The key focus of the experiment is to increase crop yield and produce high quality harvest. Observing and understanding different types of crop performance and growth under varying conditions like soil, grazed/un-grazed, water and nitrogen content can greatly help in increasing the quality and quantity of crop yield.

In the sequel we outline how OpenIoT has been exploited in order to support the above-listed experimental tasks.

4.2. Implementation and Deployment

Phenonet is supported by a production system with commercial quality grade software and unit tests developed for researchers in CSIRO and government organizations in Australia. Phenonet platform is currently being used in daily basis and enjoys high level of uptime and very stable code.

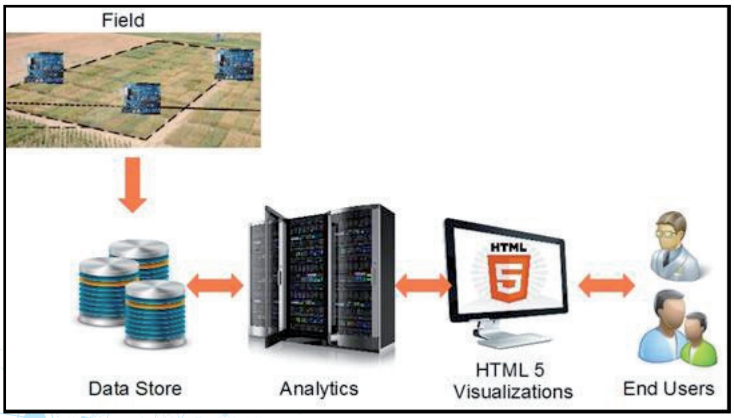

Figure 4: Phenonet Architecture

The high-level architecture of Phenonet project (depicted in Figure 4) consists of five stages:

- **Field**: The field is an experimental plot comprising different types of crops varieties. Wireless sensors are installed in the experimental plots that measure various environmental features such as soil temperature, crop canopy temperature, humidity, wind speed etc. Using this information, the crops growth, performance, size, etc. are continuous sensed/computed in real-time.
- **Data Store**: Data Storage highlights the need to have all captured data and information about the data (metadata), to be stored in a safe location. At storage state, we are targeting both sensor measurements and metadata information. Examples of metadata information include; sensor types, serial numbers, MAC address, experimental treatment, crop sowing date, genotype, replicate number etc. Each sensor stream is identified using a globally unique identifier (GUID). This layer in current Phenonet relies on python scripts to upload data into the system.
- **Data Analysis**: This is the brain behind all the calculations, data modelling, and data cleansing and linear aggregation models used by Phenonet project. This component directly contacts Data Store layer when it requires data from a particular stream. Internally, Data Analysis component also performs extensive caching and applies proprietary algorithms and mechanisms to ensure a highly responsive interaction with the system is maintained at all times. Data Analysis component is accessible through HTTP RESTful API. The response to any request received by this component is in format of JSON object.
- **HTML5 Visualization**: This component is responsible to generate RESTful network requests and send them to data analysis component. The response is then rendered by the frontend and appropriate visualization components. This layer is written in CoffeeScript and uses HTML5 for rendering and visualization.
- **End user**: Ranges from a plant biologist to a farmer. The system also provides tools and mechanisms to share data analysis and visualizations with other group of users.

In Phenonet, a user is a logical entity (e.g. a project or a research group), which owns a group of experiments. An experiment has only one owner. Each experiment is a group of nodes and each node belongs to a single experiment. A node can also have its location associated with it, such as latitude and longitude values. A node itself is a group of streams and a stream is a series of timestamp and real number pairs with a unit of measurement. Metadata can be attached at every hierarchical layer. In general the following polices are enforced on the data model.

- Any user can have zero or more experiments.
- Any experiment can have zero or more nodes.
- Any node can have zero or more streams. Each node can also have latitude, longitude and altitude values.
- Any stream is a set of (timestamp, value) pairs. Each stream has one unit of measurement.

The mapping of a typical field experiment is illustrated in Figure 47. In this example, the experiment is an ordered arrangement of 2 m wide by 6 m length plots. The plots are subdivided into experimental units and are mapped to the node level in Phenonet. On some of these experimental units, measurements of soil moisture are made at multiple depths. A measurement of soil moisture at a particular depth is mapped to the stream level, associated to a node. In summary, the stream maps to the physical or virtual sensor that monitors a phenomenon while nodes and experiments are used for grouping at different levels.

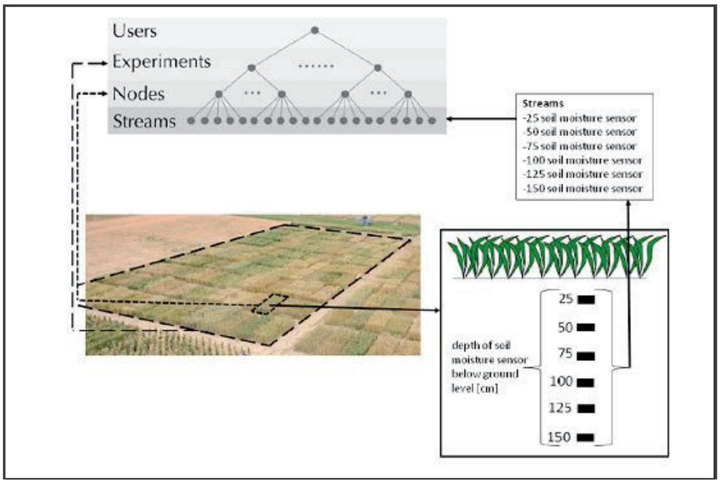

Figure 5: *Typical field experiment mapped to the Phenonet data model*

The metadata associated to each of the levels is critical for providing contextual information. In the above example, for the experiment level, metadata could include information such as the year when the experiment was run; the date the experiment was sown; description about the objectives of the experiment and even descriptions about the experimental site like e.g. soil type. At the node level the most important metadata fields are the genotype and the relative location of the experimental unit within the experimental plot (in most cases for this application a row/column notation is used). Treatments applied to individual experimental units can also be appended as metadata at the node level. At the stream level, in this example the depth, the sensor type and the sensor serial number are the most important metadata fields, while sensor information like the date of calibration or settings of the sensor can also be critical.

Based on the Phenonet-OpenIoT integration, an experiment is composed by the end-user (a farmer or a scientist) by discovering relevant sensor data required for the experiment. For example, to compose an experiment, an end-user searches for soil moisture sensors at different depth and compose an experiment/service for each of the discovered sensor. The location of the sensor is mapped to the node location of existing Phenonet application. The metadata for a given experiment are then added to the description of the experiment when composing the experiment using the Request Definition tool. Similarly, HTML5 visualizations of Phenonet are replaced with OpenIoT Request Presentation tools that allow users to visualize the experiment's outcomes. Overall, the use of the OpenIoT infrastructure towards supporting Phenonet experiment is based on the following core modules and services of the open source project:

- **X-GSN**: X-GSN is used as the sensor streaming middleware. X-GSN wrappers will be developed to interface with the Phenonet data store to obtain real-time access to Phenonet sensor data. X-GSN will also be responsible to annotate incoming sensor data streams from the Data Store/Field.
- **Scheduler and Service Delivery and Utility Manager (SDUM)**: SDUM core services will be used to compose and deploy a Phenonet experiment on the OpenIoT platform. A service composition in OpenIoT is mapped to Phenonet experiments that comprise a set of sensors with a particular analytic operation such as average, sum.
- **Cloud Data Store and Discovery Service (LSM-Light)**: The data from existing data store are pushed into LSM along with sensor annotations allowing discovery of sensor data.
- **Request Definition and Presentation**: The request definition and presentation tools are used to design and deploy an experiment with the help of the discovery, scheduler and SDUM core services.

The development and deployment of any integrated Phenonet experiment based on the OpenIoT platform involves also the following tasks:

- **Sensor Configuration**: The sensor configuration task requires the extension of the OpenIoT ontology towards describing Phenonet Sensors, as well as the registration of the extended ontology with the cloud store (LSM). Furthermore, the Phenonet sensors should be integrated with the XGSN on the basis of an appropriate (X-GSN compliant) metadata description.
- **Content Collection**: This task involves the development of X-GSN wrappers that will allow fetching of data from the Phenonet data store. The current Phenonet system provides restful API in order to facilitate this integration.
- **Data Discovery**: Once data is pushed by X-GSN to the cloud, the data becomes discoverable using the existing OpenIoT tools namely the scheduler and Request Definition Interfaces. The Request Definition interface is used to demonstrate the discovery of sensor data along with simple proof-of-concept services composition.
- **Integrated Platform Deployment**: This task involves setting up and deploying the OpenIoT services on a local infrastructure at CSIRO. It is based on the code of the platform, which is available as open source software.

4.3. Outlook on Generalization and Wider Deployment

The integration of OpenIoT within the Phenonet project is a starting point for several interesting activities that are beneficial to both projects. In particular, Phenonet benefits from a middleware platform that facilitates the integration of new sensor types and new types of data analysis tools. Likewise, the availability of sensor data at the OpenIoT cloud can facilitate the design and deployment of additional experiments, through exploiting the richness of semantically annotated sensor data and the dynamic discovery capabilities of the OpenIoT infrastructure. At the same time, OpenIoT benefits from the availability of a practical showcase in the smart farming area, which is recently gaining momentum. Note also that OpenIoT benefits from the availability of sample smart agriculture datasets at its cloud.

The successful deployment and use of OpenIoT in the scope of Phenonet experiments is a ideal showcase for several of the capabilities of the OpenIoT platform, such as easy integration of any type of sensors, support for data collection and unification at a large scale, as well as flexible application development based on the OpenIoT tools. The Phenonet experience can therefore serve as a guide for IoT solution providers interested in developing integrated solutions in smart agriculture.

4. Conclusions

EU OpenIoT is an award winner open source project [9], which has recently attracted the attention of the IoT research community in EU and beyond borders. OpenIoT offers a unique value proposition in terms of IoT/cloud integration, but also in terms of the large-scale semantic interoperability of distributed heterogeneous data streams.

OpenIoT comes with a set of visual tools which can greatly boost application development and deployment though supporting tasks such as sensor deployment, sensor querying, construction and deployment of IoT services, as well as monitoring of IoT services from a single entry point.

Overall, the main arguments in favour of using OpenIoT for a given IoT application/deployments include that:

- OpenIoT eases the combination of data from diverse (geographically and administratively dispersed) data sources, through ensuring the semantic unification and interoperability of diverse data streams.
- OpenIoT enables the on-demand dynamic selection of sensor data and metadata, thereby supporting the dynamic construction of IoT services. This provides support for an innovative added value «Sensing-as-a-Service» paradigm.
- OpenIoT offers visual tools that reduce the effort of IoT application development, especially of applications that needs to leverage OpenIoT’s semantic interoperability capabilities.

Despite the above-listed benefits and the research interest on OpenIoT, enterprise deployments based on OpenIoT are still in process. The presented (successful) deployment in the areas of smart manufacturing and smart farming are two concrete project use cases examples deployed as proof of concept implementation of the project’s potential to move some of its developments in the enterprise and we are in the process of validation accordingly to those resources. The presented solutions can be easily generalized due to the versatile features of the OpenIoT platform. The OpenIoT community anticipates that more solution developers will show interest on the open source project and will be keen on providing support.

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Real-Time Structural Monitoring

An IoT Success Journey: Real-Time Structural Monitoring of Barcelona's Olympic Venue "Palau Sant Jordi"

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ABSTRACT: *Worldsensing, its founders and staff, have been at the forefront of the development of the Internet of Things (IoT) by significantly advancing the state of the art in machine-to-machine (M2M) communications protocols, M2M/IoT standards and general understanding of the subject matter. Over the years, on real-time sensing products in smart traffic and industrial monitoring markets. Whilst most peers opted in the early days to develop generic horizontal platforms able to support all kinds of IoT technologies, Worldsensing consciously chose to focus on some specific industry verticals where it was able to solve well-defined problems by means of real-time monitoring turn-key solutions. The industry picked up on this vision and the notion of the Important Internet of Things, Industrial Internet as well as Internet of Everything emerged. With focus on industrial monitoring, this article describes the journey Worldsensing has undertaken from a simple inception to becoming a global market leader in real-time monitoring solutions.*

KEY WORDS: *IoT, M2M, Industrial Internet, Critical Infrastructure Monitoring, Worldsensing.*

1. Introduction

When you hear the word "Internet" in 2014, do you think of computers and Ethernet cables connecting them all? Or do the Facebooks, eBays and LinkedIns come to your mind? In 1990 it was the former; today, it is the latter. The Internet has undergone an enormous change from being technology-driven to market-driven. The decoupling of underlying technologies from the services able to run on top of it have been a painful but instrumental shift in unlocking what is now often referred to as the 3rd Industrial Revolution.

The 3rd-bis or 4th Industrial Revolution, however, is already gearing up. It is a world of ubiquitously connected objects, things and processes. It is the emerging cyberphysical world where you will have less human friends talking to you than things, your new "thriends" (and "enemings"). It is a world where we will see unprecedented opportunities being serviced using an infrastructure which will become entirely invisible. When this happens, we will see the raise of Internet of Things (IoT).

Today (Q2 2014), we do have the sensors, actuators, objects, just as we had computers in the 80s; and we are starting to witness the critical mass in connectivity needed to power this emerging IoT. At the time Worldsensing was founded (2008), however, we were still focused on achieving connectivity. At that time, inspired by the success of mobile communication servicing platforms as well as generic Internet platforms, our peers focused on developing the most generic horizontal sensing technologies and platforms in the hope that either consumers or industries would pick it up.

However, we thought differently, mainly because we sensed the market was too early for horizontal IoT platforms and rather chose to solve some very specific industry problems by means of our tailored turn-key solutions. Our hope was that we would grow our verticals in size and number until it reached critical mass to achieve a horizontal platform powering the IoT. This was inspired by the early years of giants in our field, such as Microsoft who actually started on a very specific (vertical) hardware platform until it grew to a point when it was perceived a horizontal platform (operating system) – indeed, had it been a horizontal solution, it would have worked on an IBM and Macintosh from day one.

The remainder of this article outlines the growth of the company, and then focuses on a very specific success story related to the real-time instrumentation of Barcelona's iconic "Palau Sant Jordi".

2. The Growth of Worldsensing

Worldsensing, founded in 2008 in Barcelona, and based in London and Barcelona, has become a market leader in innovative wireless machine-to-machine (M2M) and Internet-of-Things (IoT) technologies. It currently (2014) employs more than 40 staff. It enjoys exponentially growing sales worldwide, and concluded its Series A of close to $5m early 2013. Its core expertise is in providing sensing and machine-to-machine technologies and services to specific industry verticals. It has two product portfolios: one being Smart Traffic solutions for Smart Cities; and the other being Heavy-Industry Monitoring solutions.

As for smart traffic, it counts on its own smart parking product **Fastprk**; an intelligent car counting system through its subsidiary **Sensefields**; and a journey-time monitoring solution through its recent acquisition of smart traffic giant **Bitcarrier**. This allows the company to offer the most complete traffic monitoring platform worldwide, enabling it to monitor, cross-correlate and optimize both static parking traffic and dynamic driving traffic in a single platform with unique return-of-investment propositions to its rapidly growing base of customers.

As for heavy-industry monitoring, it instruments critical infrastructures such as buildings, bridges, tunnels, ports, wells, etc. It also offers seismic monitoring capabilities for engineering, oil/gas/water acquisition and CO2-sequestration purposes. It is composed of the product **Loadsensing**, which offers a wide range of solutions to digitise almost all geotechnical sensors available on the market; and **Spidernano**, one of the world's most advanced wireless seismic acquisition systems. This division is described below in more details.

Worldsensing is currently market-leader in most of above M2M/IoT industry monitoring markets. It has won numerous prizes and awards, has enjoyed a vast press coverage by the WSJ and the BBC, has shaped many IoT/M2M standards, and has driven the R&D developments in Europe through participation of numerous FP7 projects.

3. Worldsensing Industrial

Worldsensing's Industrial Division holds a product portfolio including state-of-the-art monitoring solutions and dataloggers adaptable to most commonly used sensors within the civil and geotechnical industries. All our devices have been designed to meet the requirements of the most demanding sectors, and have been implemented on many ground-breaking projects.

3.1 Example Use of Industrial Sensing

In the following, we give examples of the use of Worldsensing's Industrial solutions:

- *Structures / Geotechnics.* Focussing on all civil structures: buildings, tunnels, bridges, roads, dams, etc, it offers the assessment of the structures' health status 24/7 to ensure civil safety, since very strict safety and maintenance standards are now being required in order to avoid disasters.
- *Oil / Gas.* In this case, WS Industrial concentrates on Digital Oilfields and Reservoir Monitoring, since the need for constant and reliable assessment, predictive maintenance, enhanced production and fulfilment of HSE is a reality. To face these requirements, Worldsensing solutions can monitor all stages within the production process: exploration, upstream, midstream, downstream and transport while optimising production and ensuring safety.
- *Industry.* Any part or process within an industrial installation (pipes, machinery, warehouse conditioning, etc) can be improved by Worldsensing's solutions. Nowadays, strict maintenance is required in order to ensure quality products and safety for workers. Worldsensing Industrial offers reliable assessment which allows increased industrial production and improves the quality standards within installations.
- *Environment / Seismology.* The increasing regulations on environment quality and the need for seismic monitoring within high risk areas to react to natural or anthropic disasters can be fulfilled by WS Industrial too. Its solutions offer the remote assessment of environmental and seismic parameters, and a highly reliable risk alert system allowing for the prevention of disasters. At the same time, cross-relation of environmental data with other parameters (industrial, structural, etc) allows to enhance and optimize infrastructures and industrial processes.

3.2 Worldsensing's Geotechnical Solution: Loadsensing

Loadsensing is a wireless data acquisition system for industry-compliant sensor networks of any size, which brings true mesh multi-hop capabilities to the real instrumentation world, providing wireless datalogging networks that may be used for data acquisition in almost any sensing application.
Compatible sensors include multiple technologies (voltage, vibrating wire, 4-20mA, SDI-12, etc.) and types of sensors (tiltmeters, load cells, extensometers, crackmeters, piezometers, water quality probes, hydrocarbon detection, etc).
Loadsensing provides with readings periodically (5min to 24h) for the evolution of structures. Loadsensing's dataloggers are adaptable to most commonly used sensors within industry.
The main benefits and features can be summarized as follows:

- no cabling needed, saving expensive installation/ maintenance
- true wireless mesh network delivering data 24/7 from field to control
- remote assessment allowing for the prevention of accidents and associated costs
- alarm system to prevent structural stress and other risks
- robust and reliable solution, offering longevity within harsh environments
- easy to install, plug and use; super-intuitive free web software

Examples of the usage of said applications is shown in below Figure 1.

Figure 1: *Example usage of Loadsensing in engineering, seismic and other applications.*

4. Success Story: Real-Time Monitoring of Barcelona's Palau Sant Jordi

Loadsensing monitors load distribution and structure's equilibrium using a wireless datalogging mesh network to bring all data from the load points within Palau Sant Jordi to client's servers. The system is controlled from the administration centre and visualized on-site with high-intuitive software installed in tablets.

4.1 Introduction

The Palau Sant Jordi is a multi-purpose indoors installation, and is part of the Olympic Ring complex in Barcelona. Palau Sant Jordi was opened in 1990 and is considered a masterpiece of modern architecture and engineering. Palau Sant Jordi's roof consists of a giant, metallic web combined with glazed ceramic tiles.
Palau Sant Jordi is a multifunctional space equipped with the latest technology, but perhaps its most representative quality is the ease and speed with which any kind of production can be set up. Whether they are big concerts, sporting events, family shows or corporate events, the Palau Sant Jordi provides the perfect place for any kind of event. It is an intelligent building provided with a control centre that permits the quick and efficient management and operation of climate control, light, fresh air, sound, cameras and alarms.
With a maximum capacity of 17,960 people, the Palau Sant Jordi has a track record endorsed by 20 years of success, 20 years during which it has been the place in Barcelona "Where everything is possible". **Figure 2**

Figure 2: *Barcelona's Olympic Arena Palau Sant Jordi*

4.2 Safety Problems & Project Goals

Very strict safety and maintenance standards are now being required in order to avoid disasters and to ensure low operational costs. At the same time, a good monitoring system can optimize this infrastructure's performance avoiding unnecessary risks.
The goal of the project was thus to enable real-time monitoring of the loads applied to the roof's structural system, where the following was sought:

- weight applied to each individual load point; and
- load distribution and equilibrium in the entire structure.

4.3 The Industrial IoT Solution

Worldsensing's Industrial IoT solution consists of 153 foil strain gauge load cells (S-type) to control all load points in the structure. These load cells are read every 5 seconds by 21 Loadsensing wireless multi-channel dataloggers; the Loadsensing wireless system creates a smart auto-organized mesh network that reaches the gateway, where all data is stored, processed, and send from the sensor network to the client's and Worldsensing's servers, for 24/7 management and control through Websensing, Loadsensing's highly intuitive and user-friendly web platform and tablet app. This software displays the load state and alarms warning when a single load point or the structure's equilibrium exceeds its maximum.
This Loadsensing installation has not only saved over 4km of cables, but most importantly, it gives our client peace of mind thanks to its alarm capacities and real-time status delivery of Palau Sant Jordi's structure.

5. Success Story

The success of this Industrial IoT project is reflected in some truly competitive advantages, as well as still being operational after years of usage.

5.1 Competitive Advantages

The Loadsensing real-time wireless monitoring system is commercialized worldwide through local partners (engineering firms acting both as service and equipment providers) and international distributors (large instrumentation companies). Worldsensing offers full support and back-up for all projects of their partners, not only on providing the monitoring equipment, but also with the capacity of assist on all stages of the project's lifetime including support for data analysis. This enables a complete peace-of-mind not only for the final customer, but also for the intermediary engineering and consulting companies that deploy and supervise the installation for final user of the infrastructure.

Furthermore, Worldsensing has the capacity to face strategic projects worldwide, providing turn-key solutions for the end customer, this being for example large construction firms or energy companies. In this business modality, Worldsensing Industrial Division provides support in all phases of the project: design, consultancy, equipment provision (including hardware and software), installation, and permanent follow-up, maintenance, and data analysis. This is the case with the real-time monitoring of Palau Sant Jordi, in which Worldsensing is 24/7 giving support and survey of the installation.

5.2 Current Operational Status

These last 18 months have represented a year of success: sampling at a rate of 5 seconds, the Loadsensing system has delivered **over 1 billion precise readings in real-time** since its installation. Some more facts on the installation: 965.001.600 uninterrupted readings per year; 153 strain gauge load cells; 21 state-of-the-art wireless dataloggers; and 2 high capacity gateways.

Loadsensing deployment has watched over successful events such as the X Games, the FINA World Championships, and the World Handball Championship, among other first-class sporting events at the "Palau Sant Jordi". Many other events (concerts, exhibitions, trades, conferences) have passed through the venue whilst being carefully watched by Loadsensing and its critical-infrastructure monitoring alarm capabilities.

Careful installation monitoring combined with 24/7 equilibrium monitoring has provided over one year of complete peace of mind to our client. Safe in the knowledge that all load points are continuously maintained within safe thresholds by the Loadsensing system, our clients benefit from our high standards not only in technology but also in the key area, reliability. 23 years since inauguration, Worldsensing is really proud to carry the tradition of at Palau Sant Jordi, of safety and success ... with Loadsensing.

6. Concluding Remarks

The design of the industry-compliant wireless datalogger system Loadsensing, i.e. an Industrial IoT product, has been significantly more challenging than anticipated. From a technical point of view, the datalogger had to obey stringent requirements on resolution, sampling signal to noise ratio and sampling frequency, packaging, data delivery reliability, etc. From a business point of view, we had to bridge the long sales cycles inherent to these business-to-business (B2B) markets, and also "educate" the very traditional market of instrumentation that wireless Industrial IoT solutions, coupled into Big Data platforms, is indeed a major competitive factor in the industry. The success of the project of the Palau Sant Jordi, as well as many other international projects Loadsensing is involved with, demonstrates that a European SME can be globally competitive by being ahead in the innovation curve. Worldsensing, backed by the knowledge of its founders and the learning curve over the years, has achieved precisely that in the Industrial IoT market space.

City aware Smart Shopping Service

Merchants exploiting real-time city information

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ABSTRACT: *The popularization of information technology in the recent years has boosted new paradigms such as IoT and Smart Cities. Furthermore the rising of the penetration of smartphones among citizens enable a new way of interaction between people and the cities they are living in. This direct link facilitates a closer relationship and a better understanding of the utility of new IoT devices deployed across cities. The data generated by these devices provide a real-time picture of the status of cities, and since cities are aware of the potential of the information they are offering through open data platforms the opportunity for the development of new services. This work presents a novel approach for taking advantage of this ecosystem by the creation of a Smart Shopping service in Santander city. This service focuses on providing tools to merchants for maximizing their revenues thanks to IoT.*
KEY WORDS: *Smart Shopping, Context-Aware, Open Data, SmartCity engagement*

1. Introduction

The democratization of technology and the penetration of the Internet of Things in multiple scenarios are facilitating the rising of new models of traditional services. This situation is having a strong impact in cities since the economical savings that can be obtained represents an opportunity for modernizing old infrastructures and opens the door to the development of novel services. Based on this idea the Smart City paradigm has been already introduced in our daily live and it is becoming more and more effective with the growth in the developments.

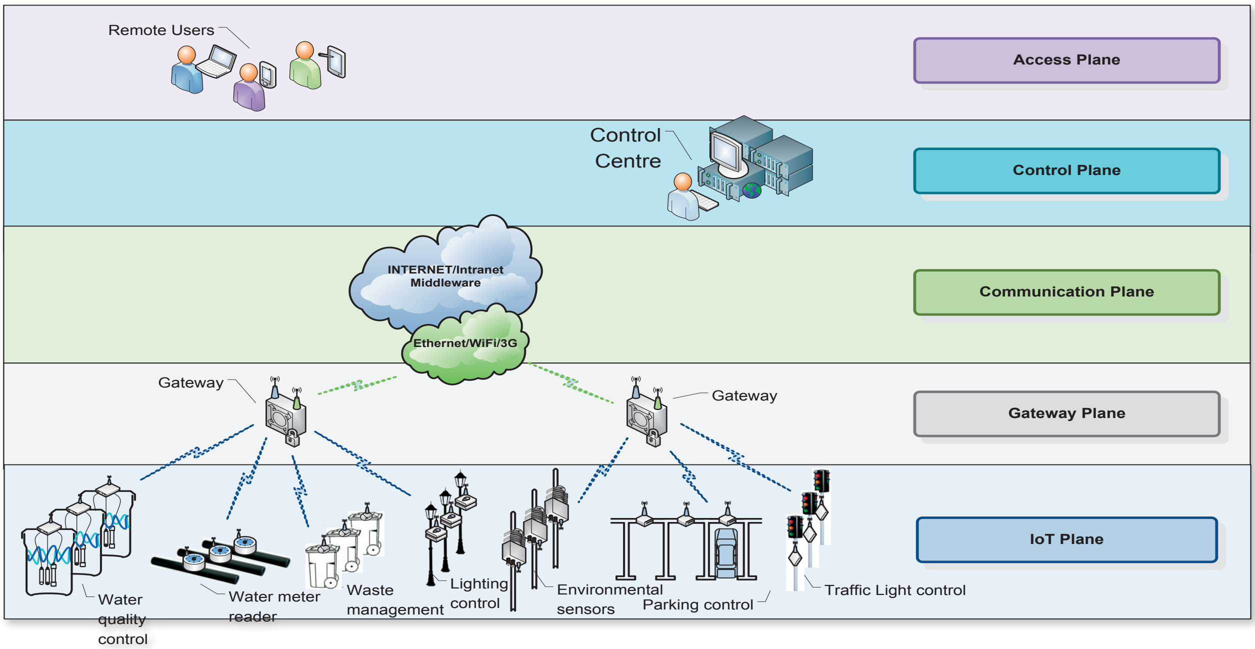

***Figure 1 :** Smart City use cases*

This new concept implies also the possibility of opening part of the information collected by the city to third parties interested in expanding the available services thus increasing the plethora of applications that cities can offered to their citizens. The idea of a Smart city as developed urban area that creates sustainable economic development and high quality of life by excelling in multiple key areas; economy, mobility, environment, people, living and government becomes real by the adoption of these actuations.

Santander city already has a large deployment of IoT devices sensing multiple parameters making reality the concept of Smart City. Moreover, the city also provides the technological tools that are required for exploiting the information in real time. Santander offers an open data platform and different smartphone applications for accessing and interacting with the city. This environment facilitates the development of new applications that combine specific services with the exploitation of city data in real time, but also considering the knowledge derived from the analysis of historical data and information provided by external stakeholders. These pieces compose the **context information** which can be processed for extracting the maximum benefit for each service or use case running in a smart city environment.

In this work it is presented a **Smart Shopping** service able to process in real time city status for creating alerts for the merchants. These alerts inform about potential presence of customers that fit with business profile so as to allow merchants to get the maximum benefit from those situations.

In the following sections it is described how a smart city environment facilitate its development, which are the key technical enablers for its deployment, the most important parties involved in the development process (municipalities, banks and SMEs) as well as the actors and the roles they are playing in the shopping scenario.

2. Smart City context

2.1. Santander as Smart City

Santander (De la Serna I. 12) city has decided to promote a new city mode based on innovation and development of novel technologies focused on Future Internet (Santander 14). In this context the city has participated in several initiatives for populating the city with multiple IoT devices providing information in real-time about different parameters and transforming the city into a Living Lab for testing novel applications.

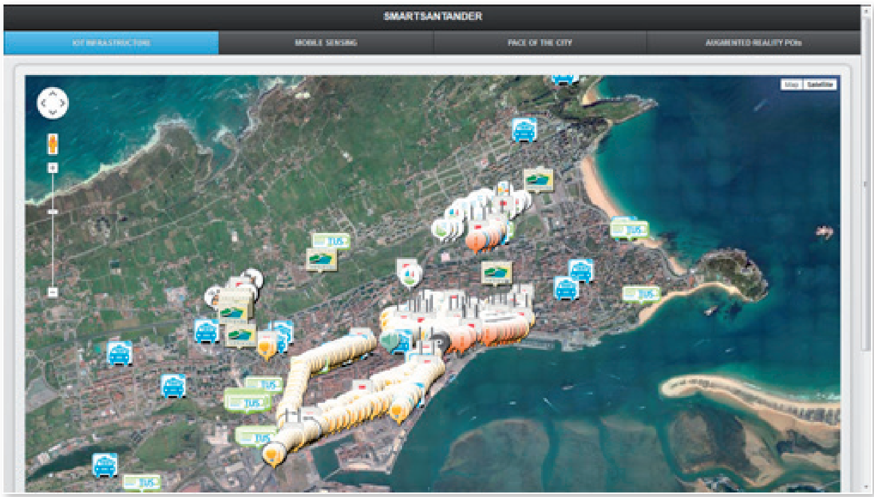

Figure 2: *Santander City IoT deployment*

There are several applications already running in the city, however they are focused on monitoring or efficient management of resources. Nevertheless, the possibilities these data offered are huge and the available open data platform enables the rising of new services exploiting the knowledge about the city and its citizens' behaviour. In addition, the city application provides a direct channel to communicate city and citizens creating a stronger engagement situation between them and fulfilling one of the key requirements for the success of Smart Cities.

2.2. Santander Open-Data Platform

As it was aforementioned, one of the key enablers for the development of the smart city concept in the city is the Santander Open Data Platform. This platform offers a catalogue of data covering different aspects and activities of the city and the required technical mechanisms to automate their collection. The use of the information produces added value services on top of the sensing infrastructure already deployed in the city.

Figure 3 *Santander Open Data Catalogue*

The catalogue has the data organized in several areas related with the different activities , the following lines will explain these areas and the data stored in each of them:

- Transport. This category includes geolocated information about the bus and taxi stops, the location of parking spaces for disabled people, motorbike parking, tracking of public transport and status of traffic in the city.
- Urban planning and infrastructure group contains data related to maps, assignment of zip codes based on location, park areas, identification of districts, construction licenses and information about city districts.
- Merchants information related with business location and data, pop-up stores and special events and news involving merchants.
- Demography which refers to current population and its evolution, and also historical evolution of demographic information in the city.
- Society and Wellbeing covers digitalize version of notification and news of social care services of the city.
- Culture section includes the agenda of events in the city, the working days and the news related with events that will be perform in the city.

2.3. Santander city digital tools

In the previous section it has been introduced the open data platform as a key element in the context of this work. But the city also provides other digital tools that enable a direct interaction among the city and the citizens.

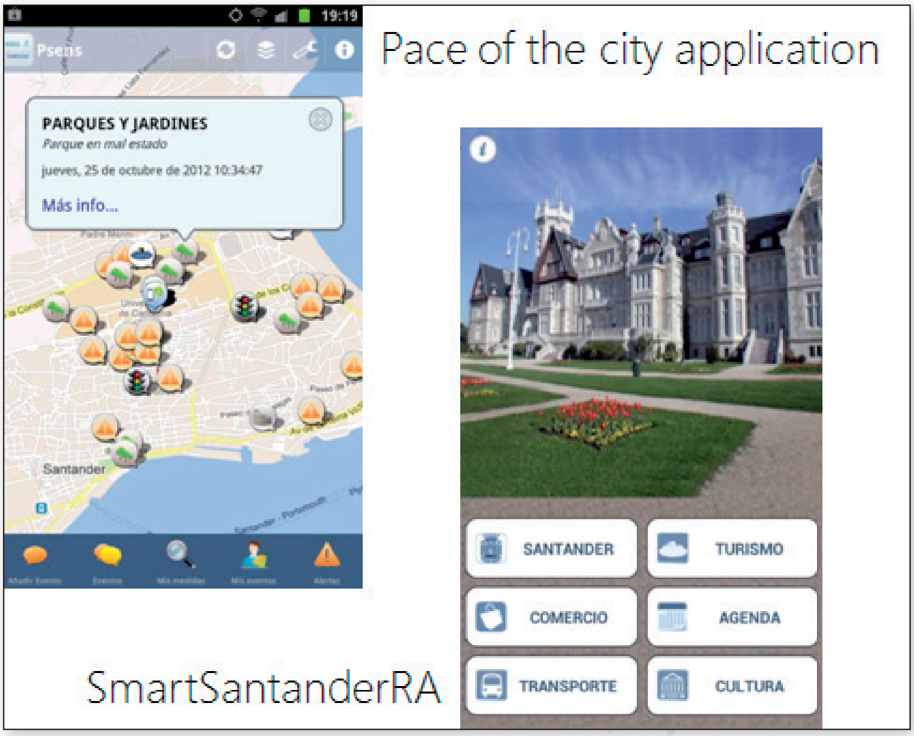

Figure 4: *Santander citizen's city tools*

The first tool is the **Pace of the city** (Gutierrez *et al.*, 13) application, it creates a direct link between citizens and the city allowing people to report problems in the city directly to the municipality and thus minimizing the time between a problem is identified and its solution. Furthermore the application is not only a reporting mechanism, citizens can also check in real time and useful information about city status.

The second application is **SmartSantanderRA** (Gutierrez *et al.*, 13). This has been created as a simple and visual access to city information. SmartSantanderRA is of special interest for this work due to the Smart Shopping service will be included in it. The integration of the service will be deeply explained in the definition of system architecture.

3. Smart Shopping

3.1. Existing solutions

The commerce application (C. Dahlen 12) existing in the market rely on the amount of users they have behind, so the merchants trust on the statistics for getting new customers once they upload a new advertise. However, although this is a good opportunity for getting new prospects, they are using a very limited range of available information for increasing the impact of their ads.

A good example for showcasing how these services work is the dissection of the most successful one. Groupon offers a free online advertising platform with access to multiple geolocated potential customers. Moreover, Groupon shares the email of its customers with the merchants after a first purchase, then the merchants receive the email address of the client providing direct access to them. This service offers a very effective way of accessing thousands of people in a fast an easy way, however they takes half of the price of the promotion. But according to Groupon statistics 97% of business use the service after the first time.

Discount brouchers tools is a service which is currently almost saturated, there are lot of different possibilities selling the same product and the only difference among them is the amount of potential customers in their databases. In this situation and thanks to the evolution of IoT and Smart Cities this work presents an approach that customers are the final beneficiary, but adding value by serving to merchants knowledge of the environment and city allowing them to exploit *hot* deals.

3.2. IoT as key enabler of a new shopping paradigm

As commented in previous section, the existing solutions do not exploit the recent advances in IoT, not only the activity of a single user is relevant for a market, also how the whole group of individuals behave is important. The current IoT deployments in Smart cities provide new resources that are relevant for increasing merchants' activity.

In this context of Smart Cities, IoT represents a disruptive advance for providing not only a good method for attract new clients to local businesses, but also a tool for exploiting real time status of cities so as to increase the impact of the advertisement campaigns. The benefit of the new approach relies not on the aggregation of lot of information but in the selection of the key aspects that induce a system to the identification of opportunities.

The next figure synthesises how this new paradigm works. The multiple sources of information (banking, geolocation, activity, city agenda, parking availability...) handled and managed properly derive into a push notification system for alerting merchants in real time about the opportunities the city status is offering them.

With a clear view of how IoT and Smart Cities are able to increase the effectiveness of Smart Shopping systems, the next sections will detail the way for transforming these ideas into real systems in an operational environment.

Figure 5 *Combination of information for analysis in a Smart Shopping environment*

4. Smart Shopping Implementation

As aforementioned the idea of the integration of IoT in a Smart Shopping system requires from several action; identifying the key players, define a technical architecture for supporting the new features, define the flow of information for minimizing the idle time in the application and the tools that have to be provided for maximizing the use of the service.

4.1. Smart Shopping actors

As aforementioned the idea of the integration of IoT in a Smart Shopping system requires from several actions a clear definition of the actors involved and the activities they will perform in it. There two main actors in addition to all the data management included. These are the merchants and the citizens. They are design to perform different roles, the first receive and analyze information generated by the city, and feed the system with information to be delivered to the citizens. These are the second actor, they are in charge of accessing and consuming the information generated by the merchants, and based on the information they consume, update the digital platform for learning citizens' habits.

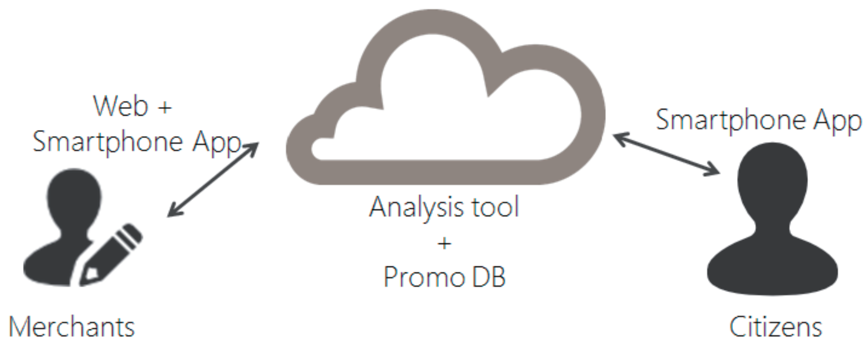

Figure 6 *System actors*

4.2. Smart Shopping architecture

Considering all the elements of the system, the interaction among the different parties involved in the Smart Shopping scenario and the available tools already working in Santander city require an adaptive architecture flexible enough to be adapted to the existing pieces and also with the possibility of integrate new ones.

The pieces already in the architecture are:

- SmartSantanderRA. This application is required for the visualization of the promotions updated by the merchants. It is the base for the interaction between citizens and the service. The application will provide an update to the existing user that includes all the access to the new Smart Shopping service.
- Content Manager. This is an intermediate element between the Smart Shopping service engine and the SmartSantanderRA application. Currently it is in charge of having stored locally part of the different services data for quick serving to users the information demanded thus avoiding long loading periods which end with poor user experience.
- SmartSantander services. The Smart Shopping application requires from some specific data generated by the SmartSantander services (Sanchez *et al.,* 11). So far the service is using information derived from monitoring of parking spaces and whose results are not open to common users, but the architecture allows integrating further information coming from this source.

Furthermore, not only the integration of existing components is enough, it is also mandatory to create new blocks in the architecture for running the new Shopping service. These blocks are in charge of interfacing and running the different algorithms ruling the behaviour of the service. There are three major activities with specific blocks in the architecture that are considered; Context management, Security and real time interaction.

- Context Management. The context of the city is the result of gathering open data (Domingo A. 13) information, information provided either by SmartSantander services or provided by external stakeholders. However, the information itself do not generate added value so this block runs the information management algorithms enriching the Smart Shopping service.
- Security. The information provided by the merchant is critical since it represents a commitment of their business with the citizens. For this reason it is mandatory to provide a reliable and secure link between merchants and the platform. Security becomes a requirement of the system, not only in terms of protocols, but also in how users deal with the tools they have.
- Real time. Since the exploitation of context information is valid in the short term, it is required to include an element that facilitates such interaction. This is made possible through a smartphone app specific for the merchants.

The following figure depicts the relationship among the different elements.

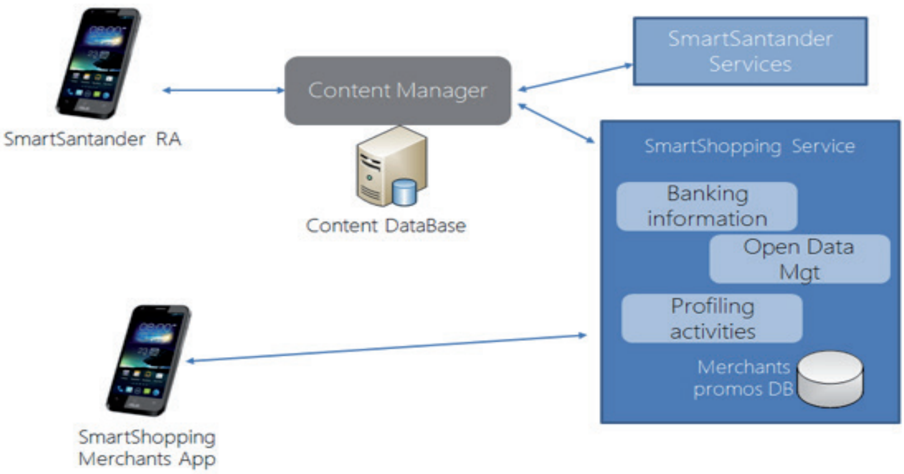

figure 7: smart systems shopping architecture

4.3. System flow

The Smart Shopping service performs different functionalities and these functionalities imply diverse internal procedures. The two key features are, serve offer information to citizens, and enable merchants to update their profiles (include new promos, track their results and edit business information).

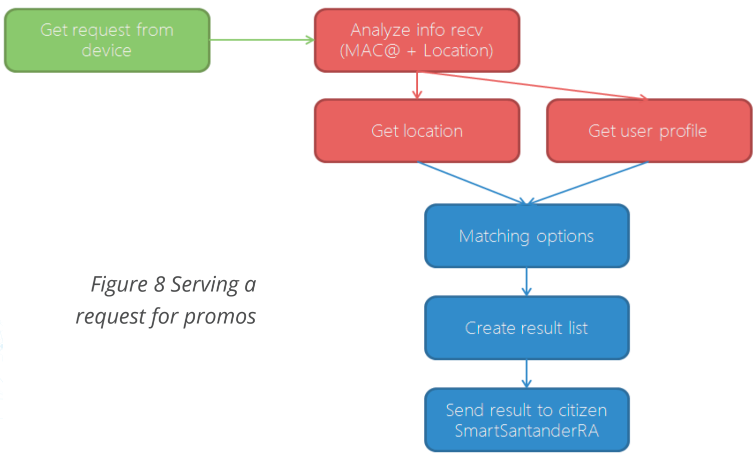

Figure 8 Serving a request for promos

The information request to the Smart Shopping service is processed as presented in the previous figure. The user interaction with the SmartSantanderRA app tries to access to the shopping information. This is transformed in a request for information using which includes the GPS location and the MAC address of the device. These two parameters are used for detecting the preferences of the device, and based on its previous activities and the location, the full list of available opportunities in the city is filtered. At that point the engine crosschecks the device profile and the subset of results and orders the resultant list sending it back to the user device. Finally the citizen is able to check on its device the different offers available, having the possibility of seeing them in augmented reality, or in a profile based ordered list. On the other hand, the system needs to be fed by merchants, and merchants need to be alerted by the service. Due to the real time analysis of the available information which reflects the status of the city, it is possible to predict potential presence of people in some places. But creating alerts is only the first step, the notifications should be delivered directly and only to those merchants who can benefit from them. In order not to spam merchants and also to maximize the ratio notification-new client, it is extremely important to accurately select the group of receivers. The flow the system follows for implementing this feature is presented in the next figure.

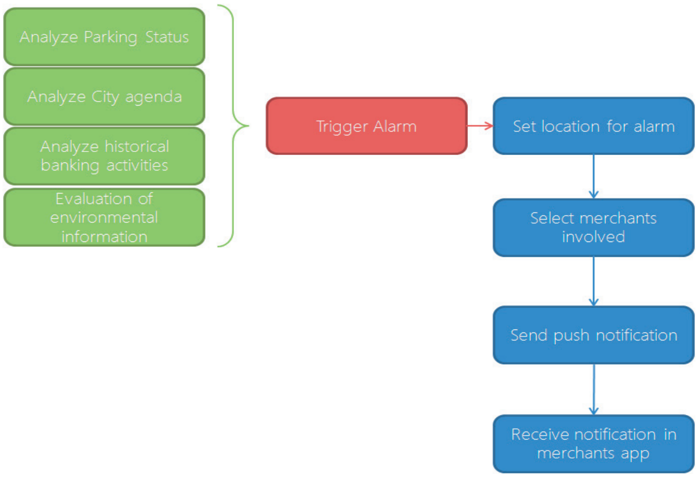

Figure 9 *Merchants notification reception flow*

4.4. Merchant tools

One of the strongest requirements is real time interaction between platform and merchants, however the penetration of smartphones is not as high as the use of internet among the merchants. Due to this, the definition of interfaces between them and the service represents a challenge in order to facilitate and boost the use of the platform. The Smart Shopping service offers a website to merchants for accessing and uploading information about their business. But web interaction is not convenient for real-time interaction, for tackling this need the service is also providing a smartphone app with the capability of receiving push notifications that reduces the time between an alert is generated and a merchant reacts to it.

In both cases the interface and interactions have been simplified as much as possible, and in every interaction the minimum amount of actions are required for access to specific information of existing campaigns or for uploading new ones. The merchants has actively participate in the design of the interfaces, since they are the final users, they had the possibility of giving feedback for the possibilities initially presented, they way they interact with the platform, and the information required for creating new promos.

The following figure presents an example of the exchange of data between a merchant and the smart Shopping Service. This is done in three simple steps, login, insert the data and confirm it.

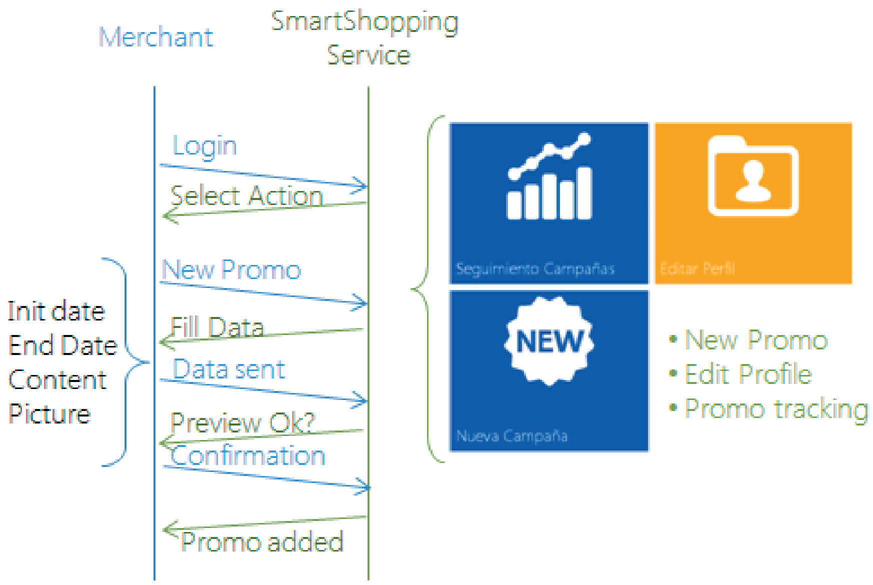

Figure 10 Flow chart for uploading a new promo

5. Conclusions

One of the main problems in Smart Cities is citizens' engagement and IoT offers a huge gap for improving people's life. However it is mandatory to consider the technical capabilities of the final user so as to bridge the digital divide by creating simple and effective services (Manged *et al*., 14). The Smart Shopping service is a good way to approach to people tangible benefits of smart cities and IoT.

This work presents an alternative view for the SmartShopping concept focused on improving merchants' possibilities and knowledge as a way of increasing citizens' opportunities.

The service presented represent another step for reinforcing the relevance of open data platforms as a way of promoting novel technological solutions the make cities smarter in many different ways. The future of open data platforms depends on the amount of application creating added value on top of the raw data available. Its use will open new business models (Walravens *et al*., 13) and possibilities for exploiting and maintaining the current smart city infrastructures. The involvement of more parties supporting the services shall be done with a clear approach for creating win-win situations.

The design of the context management engine has been done in a modular way so as to be ready to the expansion of the IoT to further data thus making its integration in the platform easy and feasible.

The proposed service is being integrated with additional tools to make it more social, this way the integration between the city, the technology and society will be linked enriching the user experience of the whole service. Merchants will have direct feedback through different channels, and citizens will receive more information from combined sources.

The city of Santander is a perfect environment for piloting these kind of services since it has a size big enough to validate the concepts and also already has an IoT infrastructure that facilitate the exploitation of context information coming from multiple sources.

The participation of Banco Santander in this project as information provider is considered as a relevant milestone since the Smart Shopping service is considering the tracking of economic activity in the city provided by the biggest bank in the country.

Finally, the current status of the service is stable enough to be replicated in other cities, but since the range of valuable context information could be increased by other sources, it would be desirable to grow towards that destination in the future of the platform. And a possible enhancement would be also to introduce a payment method for citizens so as to take advantage not only of on-site clients, but also online who want the offer, but do not have the possibility of going to the physical business.

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Health

RFID makes surgery safer

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ABSTRACT: *This document presents a novel technique to reduce the risk of forgotten surgical towels in surgery. It is an application of IoT in field of healthcare. Integrating RFID tags into towels and developing an application to read this information allow nurses and surgeons to track the surgical towels and ensure that there are no retained foreign bodies in the abdominal cavity before ending the operation.*
KEY WORDS: *RFID, Surgery.*

1. Introduction

In surgery, to clean the surgical field or to remove blood from the surgical side, typically surgical towels are used. Additionally because of their size and the used materials, they are ideally to be placed under organs to get a better exposition or to remove organs from the area of interest. According to the surgical guidelines these towels have to be counted before and after operation to ensure, that all material is removed out of the abdominal cavity before closing the incision. However, the problem of retained foreign body continues to be relevant. The incidence of retained foreign bodies is reported with every 1/3000 to 1/5000 cases still very high (Cima *et al.,* 2008), (Gayer *et al.,* 2011), (Stawicki *et al.,* 2009) and has therefore to be reduced by novel techniques.

Internet of Things (IoT) goal to connect devices that are being used and let them communicate and share information fits into our solution. If we can identify abdominal towels, track them and share their location to other systems, it would help in reducing number of cases where towels are forgotten.

2. Problem

Even by consequent counting before, during and after the operation of unused and used towels the balance is not always correct. However, the lost towel has to be found, often therefore dustbins in the operation room have to be emptied, and as last chance the surgical field has to be scanned by X-ray to be sure, that nothing retained in the abdominal cavity. Thanks to a dedicated metal stripe in the towels, these are mostly detected in the radiographic imaging. Nonetheless, there are positions, i.e. under the rips, where even in X-ray these metal stripes cannot be detected and then objects retain in the surgical cavity.

Typical risk factors are emergency operations with unplanned changes in procedure and patients with higher body mass indexes, as well as operations with changing teams. Estimates suggest that such errors occur in 1 of every 1000–1500 intra-abdominal operations (Gawande *et al.,* 2003).

Main complications are intestinal obstruction, discharching sinus, abscess formation, and peritonitis. It is reported that the morbidity rates of up to 40% and mortality to 5% (Wan *et al.,* 2009). However, each case is not only incriminating for the patient, but has also legal and eventually penologic consequences for the responsible surgeon.

3. Solution

In order to solve this problem, the surgical towels will be equipped with RFID tag (see Figure 1) so that each towel can be identified. Multiple RFID antennas are installed in the operating room. By installing these antennas, it is possible to track the towels and be sure that no towels are missing or forgotten in the abdominal cavity. The solution helps nurses and surgeons by providing intuitive way to visualize the position of towels (which represent the “things” in context of our solution) on a central display in the operating room and also tablets used by nurses. Users of our solution can easily detect if there are missing towels by one glance into the display or the tablet. Total count of towels and count of towels in the reading rang of each RFID antenna is displayed as well (Kranzfelder *et al.,* 2012).

Figure 1. *Surgical towels with integrated RFID tag*

Additionally, a repository is generated; where the number of used towels is stored among other data in the private cloud for further analysis or queries. Secure SQL server technology () is used in the repository. This repository can be shared with other applications that are part of the surgical theatre of Klinikum rechts der Isar, the teaching hospital of Technical University Munich to integrate the data of different views of the surgical work flow. To deal with the repository (e.g. register new elements or update or query exiting ones) we used Context Broker Generic Enabler, which is one of FI-WARE Generic Enablers[1]. Generic Enablers are applications developed by partners of FI-WARE to promote Future Internet standard supported by European Commission and help developers to develop their applications more easily by using these already-developed Generic Enablers in their applications.

This project is selected to be part of Future Internet: Social and Technological Alignment Research (FI-STAR) project supported by the European Union. FI-STAR aims to use Future Internet (FI) in applications in healthcare sector while implementing reverse cloud approach by using "software to data" paradigm to handle increasing concerns of using cloud computing due to sensitivity of data in the healthcare sector.

1 : http://catalogue.fi-ware.org/

4. Detailed solution

The solution designed to reduce this risk of retained objects by using surgical towels with an integrated RFID tag, a small radio-frequency-device which enables detection from distances up to 400mm. This device inside the towels can be read with antennas placed on the mayo stand, on the operating table and also in the waste basket. This enables us to follow exactly the number and position of each towel and make sure that before closing the abdominal cavity everything is removed. The RFID system uses radio waves in a frequency range of 13.56 MHz which is harmless to humans. An electromagnetic compatibility (EMC) test for use in the operating room has been performed successfully. The RFID chip was added before the sterilization process of the abdominal towel to be suitable for use in the operation. The special series of surgical towels was manufactured for the project by Lohmann and Rauscher, Neuwied, Germany who integrated the special RFID tags (Data Mars, Bedano, Switzerland). Used RFID readers are the industrial readers LR2500 (Feig Electronic, Weilburg, Germany), antennas are modified Moby D6, Siemens, Munich, Germany for covering the abdominal cavity, and ID ISC.ANT340/240 & ID ISC.ANT310/310 (Feig Electronics, Weilburg, Germany) for the unused towels on the mayo stand as well as for the used in the bin.

The software system consists of front end and backend components as shown in Figure 2. Front end contains the antennas connected to FEIG LR 2500 RFID readers. Readers connected to a server located in the operating room via serial port. Multiplexors are used to reduce number of readers by connecting multiple antennas to one reader while keeping the ability to distinguish inputs of each antenna. The application is designed to handle different readers/multiplexor settings and different number of readers by only modifying a configuration file. For our solution we divide the antennas into three major groups that we want to track towels on them; mayo stand, which is located in front of non-scrub nurses that all the tools and consumables including towels are located in start of the operation, the operating table, where the patient is located and the operation is taking place, and the waste basket, where the towels are disposed after use. Nevertheless, the application can handle arbitrary number of groups by setting the groups associations in the configuration file. Back end system is the database repository which is used to store the data of the application.

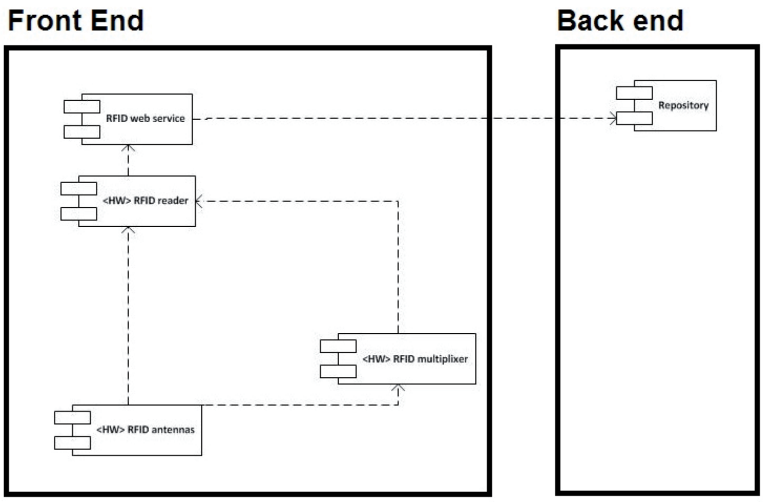

Figure 2. *Architecture of the system*

Web service technology is used to collect the data from the RFID antennas and make them available to clients, e.g. the systems that need this information, via REST and SOAP interfaces. We developed a web service to be deployed on the machine where the RFID readers are connected. The task of the web service is to passively query the RFID readers and multiplexors to get the RFID tag IDs associated with every antenna. When a client sends a request to get this information, the web service responds with JSON or SOAP message contains the number of RFID tags and list of IDs associated with each antenna. The type of the response whether JSON or SOAP XML depends on the interface that the client is using to call the web service. The status of the system (i.e. number of towels in each position and missing towels) is accessible through the web service and can be accessed via the internet if needed.

Design of the web service is shown in Figure 3. The main class of the web service is *RFIDservice_axis* which is deployed on Apache tomcat web server. It contains *configuration* object to hold the system configuration and *RFIDsystemInfo* object to hold the data of the RFID system information e.g. what are the elements in the range of each antenna and number of elements that each antenna reads. Operations of *RFIDservice_axis* allows to initialize the RFID readers (method InitSystem) and to mark start and end of the operation as well as reading the information from RFID antennas (method *getRFIDSystemInformation()*) that calls the private method *UpdateRFIDSystemInfo()* to update *RFIDsystemInfo* local object. In case patientId is not needed *getAntennaInformation()* method can be used to retrieve the data of elements in range of RFID antennas. *isActive()* is used to check if the web service is online or not.

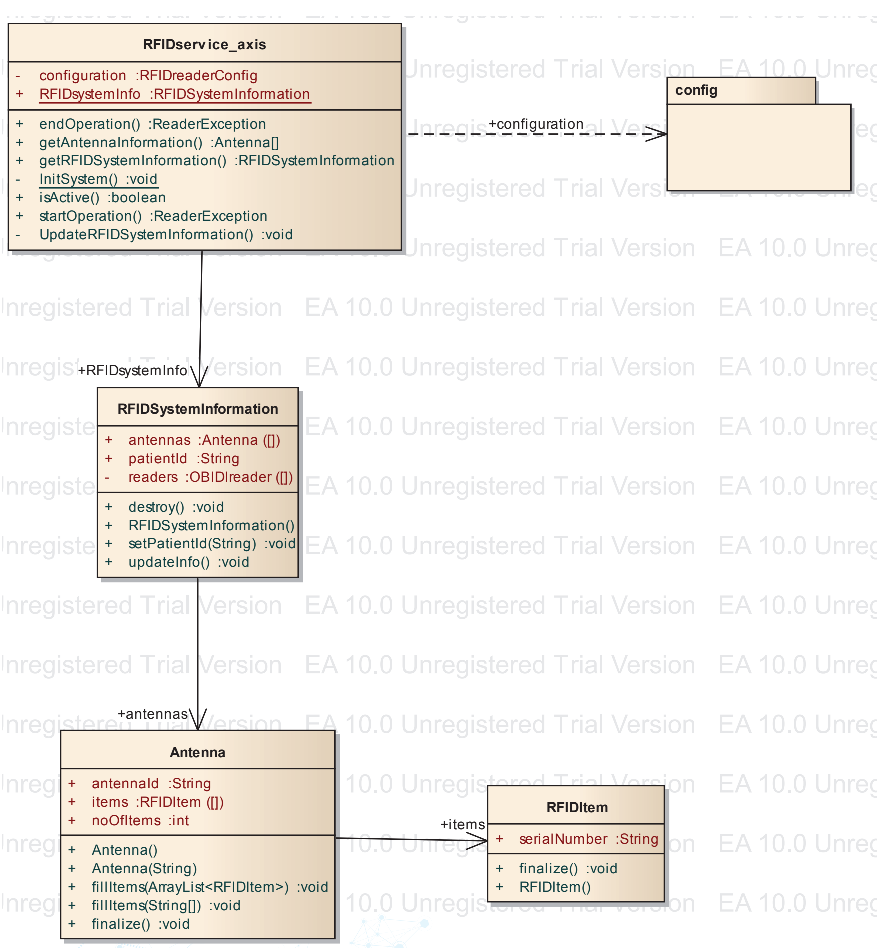

Figure 3. Web service design

Figure 4. Screenshot of application

The display and tablet will show status of the towels as shown in Figure 4. It will allow nurses and surgeons to know how many towels are not used yet. Additionally they can check how many towels were used and how many of them are still in abdominal cavity and how many are thrown away as well as if there are any missing towels that are registered in beginning of the operation but not found neither in the basket nor in the patient.

This solution is a first step in using IoT technologies in the hospital. It is proof of concept of how IoT can be useful in surgical application. Trials to include other consumables that are used in the operation and surgical tools are being held.

5. Current status and future work

Surgical Towels with integrated RFID tags are not yet available on the broad market. Currently these are purpose-built and have to be certified in a complex process, which makes these towels not useable for routine use because of the high price.

The first prototype of the complete reading system is working in the Klinikum rechts der Isar, TU Muenchen, but not yet used routinely in operations. However the final product could be released ad hoc if the towel price decreases or the operating room team asks for.

Surgical towel tracking solution is planned to be integrated into Operating Theatre Monitoring solution in the hospital, which is used to visualize the state of the surgery. Also another application to register the consumables used in the operation using 2D bar code is another application of IoT in the operating room. By integrating these solutions we can expect better documentation of the surgery as well as the safety of the patients. Also by storing these data in central repository allows analysing the data by pattern recognition techniques to detect any inefficiencies or unfamiliar situation in addition to optimizing the surgery workflow.

6. Conclusion

Identifiable surgical towels by adding a RFID tag into them can be tracked in the operating room. Tracking towels by placing RFID antennas in important locations in the operating room decreases the possibility to forget them inside the patient and to be sure that all used towels have been already disposed.

Acknowledgements

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Michael Kranzfelder, MD, is a general surgeon working in the Department of Surgery, Klinikum rechts der Isar, Technical University since 2006. Besides his clinical work, he is responsible for the research section "RFID" and "Workflow Analysis" of the research group MITI from the medical side. Dr. Kranzfelder is the author of several journal publications and conference contributions. He is a member of the German Society of Surgery (DGCH), the CTAC – Group for computer and telematics assisted surgery in the German Society of Surgery and the CURAC – Computer and robotic assisted surgery.

Armin Schneider obtained in 2006 his MSc. in biomedical engineering and did his Ph.D. degree in 2010. Since 2008 he is the scientific head of the research group MITI for minimally invasive therapeutically interventions in the Klinikum rechts der Isar der TU Muenchen. Already in 2004 he started to equip a high tech operating room with different sensors to record and to analyze the intraoperative workflow and to make surgical procedures more transparent and safe. With his team he developed methods for prediction of surgical phase times based on preoperative data as well as tools for detection of critical intraoperative workflow changes. Apart to the clinical research, he is involved in the development of new surgical instruments and mechatronic systems. He is a member of the CTAC – Group for computer and telematics assisted surgery in the German association for surgery and the CURAC – Computer and robotic assisted surgery.

Nature Monitoring

MONNA project : connected birds !

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ABSTRACT: *Monna plans to launch Europe into global leadership in technology for the monitoring of nature as a means for effective public policies on environmental management and biodiversity.*
It combines technological development for the analysis of bird migrations through European-based emerging technologies in the field of geo-localization with the creation of a living-lab to launch an emerging economic sector, monitoring of nature. This project is supported by the Territorial Cooperation Operative Program (2007-2013) POCTEFA.

1- Project

Monna plans to launch Europe into global leadership in technology for the monitoring of nature as a means for effective public policies on environmental management and biodiversity.

It combines technological development for the analysis of bird migrations through European-based emerging technologies in the field of geo-localization with the creation of a living-lab to launch an emerging economic sector, monitoring of nature.

It is based on research and development of a bird monitoring platform for the exploitation of user data in the scientific-technological, academic and public fielf, asserting key information for the design of public policies on environmental issues. Its ultimate goal is to generate a dynamic launch innovations and new business structures in this area, allowing the generation of an emerging sector in which Europe can be a leader.

2- Objectives

The overall project objective is to **position Europe as reference and leader in monitoring of nature**, through developing technology standards that can be used by members of reference networks as Euring. The creation of core technology and innovation spaces allows to capture data and transform it into useful information for research organizations and public agents that can use it for the definition of public policies directed to respect the biodiversity and the environment.
To do this, **one of the specific objectives has been to develop a multi-media and multi-device platform for handling and displaying geo referenced data**. These data is now exploited in a bird monitoring system for academic, research and informative objectives. Considering the core technology developed, together with the integration and exploitation platform, there has been a will to create a node that serves individuals, companies and institutions to create a collaborative network which emanate future R & D projects. This means that this dynamic is intended to go beyond the mere creation of a platform to contribute to the creation of a "living lab" at European level, starting initially in the regions involved in the initiative and later deployed to the rest of Europe.

Figure : *The bird monitoring is possible by the "Ringing Technique", used since 1899 and consists of individual birds marking by highly trained ornithologists to provide vital data on migration patterns, demography and ecological processes.*

The final platform developed under the project enables to:

- **Generate multimedia and social networking contents with Web 3.0 functionalities**. It is focused to environmental and ornithological organizations and associations, especially those that focus on the integration of multimedia content with the information generated in their studies, call to birds, etc.
- It also includes an **application for ornithology and environmental education** aimed to different types of associations, schools, teachers, ornithological tourism, etc.

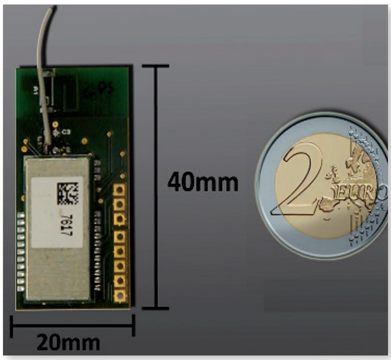
Consortium

Focusing on the goal required a multidisciplinary team. The project compromised a **highly technological character**, however, it was not circumscribed to this area and required organizations with high knowledge in birds migration movements and in the scope of the economic revitalization.

To do this, a partnership that combined the three profiles has been created, thus balancing the needs with the required capabilities.

The three basic profiles were:

- **Technological development** (Vicomtech, **Aguila Technologie** and Estia)
- **Research and ornithological and biological knowledge**. (Aranzadi)
- **Company and sector dynamic** (GAIA and Estia)



Technology used

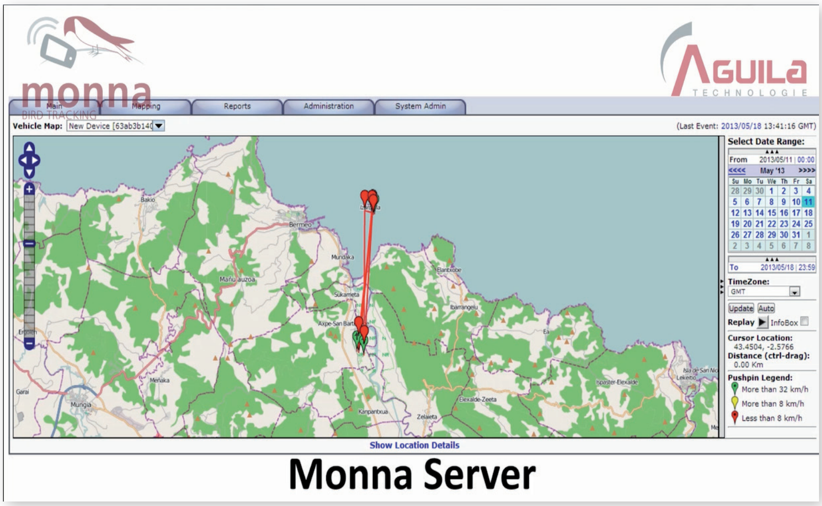
AGUILA Technologie is an independent high technology company, specialized in electronic communicating systems (Machine to Machine), with a recognized expertise in **geo positionning** and **animals monitoring**.

The tracker developed by Aguila Technologie for Monna relies on a **miniaturized high-sensitivity** GNSS/GPS geo positioning technology. The GPS used allows to receive good quality signals **even with** a very poor satellite coverage and in bad conditions.

The long range transmission system selected relies on the UNB (Ultra Narrow Band) technology. The Monna trackers use the Sigfox network, which allows a **European coverage**.

The embedded transmission carried by the bird can send data in a range up to 30 kms, to a Sigfox base station.

It has received an **Innovation award** in 2013 from the SIAD (Salon International de l'Agriculture Durable) for this achievement. During this research and development project, Aguila has been able to explore various possibilities of miniaturisation of the above mentioned technologies, with the aim to be able to equip in the future **even smaller** birds and animals.
A multimedia and multidevice platform has also been developed for managing and showing in an attractive way, the geo-referenced birds position data to **different kinds of publics**: researchers, amateur ornithologists and general public who can now enjoy this as a touristic resource.



The success of the Monna Project opens now new opportunities for animals and nature monitoring.

Public Transport

Smart City Services for Environmental Monitoring and Public Transport

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ABSTRACT: *Two smart city services developed by DunavNET addressing the environmental monitoring and public transportation utilising IoT concepts are presented. Both solutions address important areas within the range of smart city services and could potentially impact wide base of citizens living in the cities. Furthermore, original ideas for both services evolved from the past and current research projects and they are now being advanced through the further commercial activities within the company. This paper provides overview of the services from the architectural and functional perspective presenting the initial deployment results within two pilot sites in Serbia. The initial feedback and business perspectives are encouraging.*

1. Introduction

Current trend is that more and more people move to the urban areas and the UN estimates that more than 50% of people live in cities. This trend will continue and it is envisaged that by year 2050 cities will be home to 70% of the world's population (UN 2011). The cities therefore face a diverse set of challenges such as job creation, economic growth, environmental sustainability, and social resilience. Consequently, significant effort is directed towards accommodating this trend and associated challenges by developing smart city concepts and ideas and relying on IoT and ICT in general. The intention is to create new and innovative services as well as to increase the efficiency of existing services provided by the city in order to provide better quality of life for the citizens within the cities. The IoT technology represents the "glue" in mapping smart information and people together. The data and information is acquired and processed through a variety of devices, mobile and fixed sensors and actuators effectively building the IoT which shapes smart cities and associated smart services that are created and offered to the citizens.

2. ekoNET – Environmental Monitoring Service

Currently, the urban areas, in particular cities occupy only 3% of the world's geographical area but they generate about 80% of CO_2 emission. It is therefore of paramount importance for the city authorities and public and private enterprises to address this issue, identify the level of air quality and potentially act to reduce the pollution to safe levels, specified by the relevant international and/or national standards (WHO 2014). Monitoring the air quality and reducing it to the safe levels is very important for the cities and its citizens from the health perspective. Furthermore, this issue is also important as it influences cities potential to attract tourists, investors and business. If the city air quality information is transparently and widely available to the citizens, this sends a positive message that the city authorities and enterprises care about environmental issues, creating and increasing the trust that the problems within the city are being addressed and that they will be resolved.

At the same time the enterprises are continuously trying to optimize the work processes and subsequently act in a socially responsible manner. To achieve these aspirations, remote monitoring of processes including hazardous gas levels at different locations of the facility, industrial safety, personal exposure and eco-friendly solutions play an important part, in particular in the oil and gas industry (Pokrić 2014).

At present, the air pollution is mainly monitored by automatic measurement stations often operated by the government environmental agencies. The cost of these stations is very high and they require significant maintenance. Furthermore, due to their cost, they are placed far apart and therefore, this is impractical for assessing the air quality within certain city areas, for example near the particular building, cross-road junction or within the factory.

In order to resolve this problem, low-cost solid-state gas sensors were introduced for measurements of atmospheric pollutants. The most widely used type of these sensors is based on an electrochemical reaction when exposed to a specific gas. The gas concentration is determined by measuring either the sensor's output current or the resistance of the sensor's tin dioxide layer. These solid-state gas sensors are inexpensive, small, and suitable for mobile measurements.

Many research activities are aiming to address above issues, such as Smart Santander project (SmartSantander 2010) through which 20,000 sensors were deployed. Citi-Sense project (Citi-Sense 2012) aims to address this problem by development, testing, demonstrating and validating a community-based environmental monitoring and information system using innovative and novel Earth Observation applications. Within the planned pilots, DunavNET will be upgrading and deploying commercial ekoNET service for monitoring the air pollution within the schools and outdoor locations. Furthermore, this service is attracting more commercial interests and the solution will be deployed within large mine in Serbia as well as within the city of Novi Sad.

The ekoNET service provides a complete end-to-end solution for the environmental monitoring utilising the design concepts used within the IoT community such as Architecture Reference Model (ARM) as defined by IoT-A and FI-WARE projects (IoT-A 2010, FI-WARE 2011). The system comprises all the necessary components namely devices, back-end infrastructure and client applications running on different platforms (web and mobile). Utilized electrochemical gas sensors are: CO, CO_2, NO, NO_2 and O_3. The device also contains the particle monitor PM2.5 and PM10 as well as sensors for the measurements of temperature, humidity and air pressure.

Figure 1. ekoNET service architecture1 shows the high-level architecture of the ekoNET system. The ekoNET devices are connected to the ekoNET platform serving as the back-end cloud infrastructure. As it can be seen, there are several variants of the ekoNET devices depending on the deployed location (indoor/outdoor), type of sensors used (air quality/safety) and usage (stationary/personal). The collected data from the sensors is transmitted to the back-end infrastructure (Communication Server component) via the mobile network using the Constrained Application Protocol, CoAP (IETF CoRE 2013). CoAP is an application layer protocol designed to lower the complexity for the constrained networks but, also, to enable communication over the existing internet infrastructure. CoAP is a light-weight application protocol based on UDP that supports multicast requests, cashing and REST web services between the end-points, and is seen as a future protocol for IoT. CoAP is still work in progress of the IETF CoRE Working Group (IETF CoRE 2013).

The ekoNET platform and associated building blocks enable the core features such as the data storage (Data Server), data cleaning and processing functionality (Data Server and Data Processing) as well as a set of visualization widgets (Visualization Engine). Web server enables creation of the associated interfaces in order to allow communication of the web and mobile applications with the rest of the system.

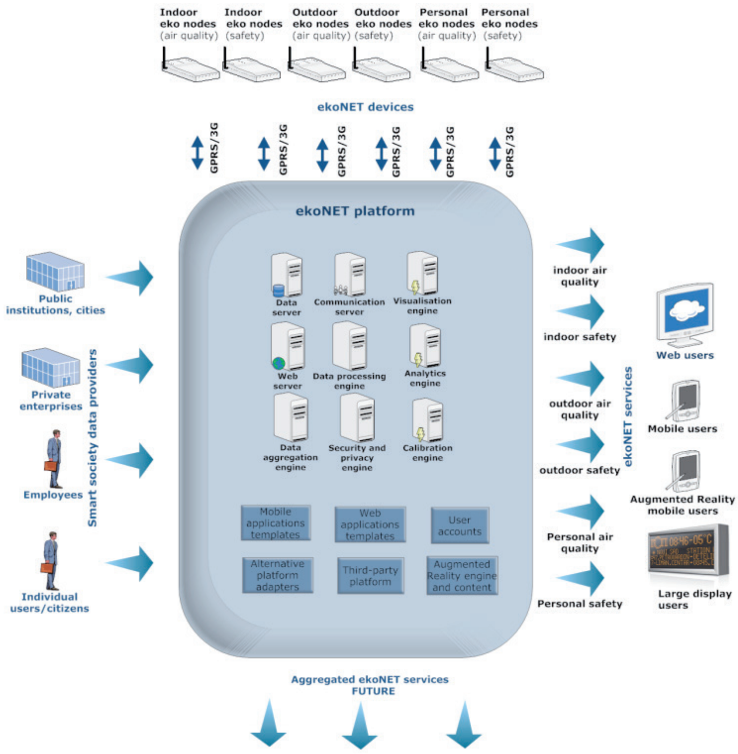

Figure 1. *ekoNET service architecture*

Analytics engine enables smart interpretation of the real-time and historical data from combination of data sources. Data aggregation engine enables creation of additional services through combination of data from different services. Data processing engine provides advanced data interpretation and preparation for visualization including the Augmented Reality (AR) content with the help of AR content generator. Alternative platform adapters enable the services to be deployed and provisioned on third-party platforms using the existing infrastructure within the enterprises or cities.

Figure 2 shows the ekoNET device with mounted electrochemical gas sensors. This version of the device is intended for the indoor usage. For the outdoor usage, an additional waterproof casing is provided (see Figure 3).

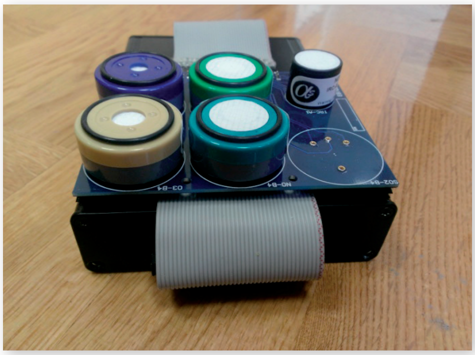

Figure 2. *Indoor ekoNET device*

Figure 3. *Outdoor ekoNET device*

Within the CITI-SENSE pilot, 12 ekoNET devices have been deployed outdoor at the same location in order to obtain initial estimate the measurement uniformity of devices and associated sensors. Figure 4 and Figure 5 show the measurements of CO and NO_2 from all 12 sensors overlapped on the same graph. The cross-correlation values of CO measurements are in the region from 0.87 to 0.99, while the cross-correlations of NO2 measurements are in the region from 0.53 to 0.89 (Pokrić 2014). All the other sensors perform in between these two extremes indicating acceptable performance, but additional calibration is required in order to compensate for the individual sensor non-linearity, specific manufacturing tolerances and effect of electronic circuitry used for data acquisition.

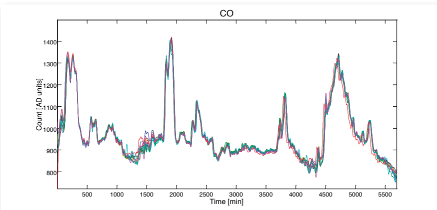

Figure 4. *CO measurements from 12 deployed devices*

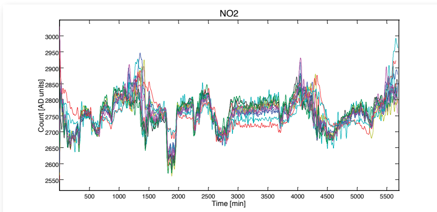

Figure 5. *NO_2 measurements from 12 deployed devices*

The ekoNET service is attracting significant commercial interest and further installations are planned in Serbia, while the plan is to expand the service offer globally taking into account the modularity and extendibility of the system whereby the customers specifies what types of measurements they require.

3. busNET – Smart Transport Service

The busNET system described represents an application of Augmented Reality (AR) technology deployed within a smart city service in the domain of public transportation. The system is being developed by DunavNET through commercial as well as research activities within MobiWallet and SMARTIE projects (MobiWallet 2014, SMARTIE 2013). The busNET service initially aims to improve the management of the public transportation network in the city of Novi Sad in Serbia starting from the public city bus transport network. The intention is to extend it to other transportation means and networks and thus promote and encourage the greater use of alternative transport modes other than cars. Further to this, aim is to provide time and cost savings to travellers as well as additional benefits to other stakeholders such as public transportation companies, city administrations and traffic management authorities. The proposed system overview is shown in Figure 6, indicating the main components within the AR powered public transport service.

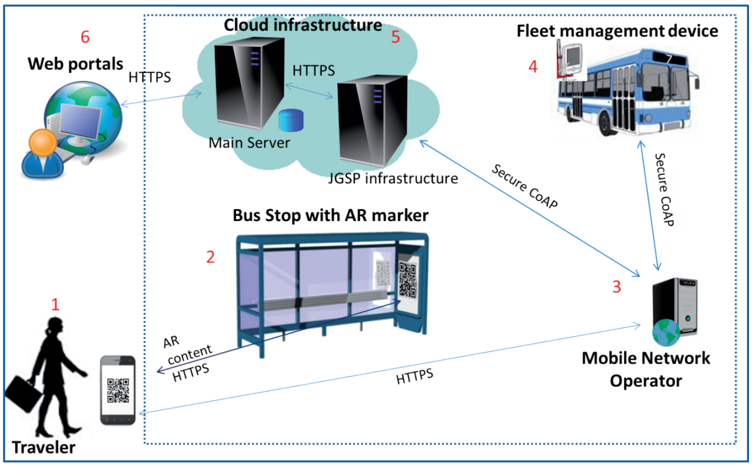

Figure 6. *busNET service architecture*

The main system components are:

1. Commuters using the public bus transport service interacting with the system (i.e. the back-end cloud platform) through personal smart phones via a secure channel, and dedicated mobile application
2. Bus stop(s) equipped with an AR marker in the form of an image (logo) or a QR code
3. Mobile Network Operator providing a GPRS/3G channel for data transfer from the smartphones and fleet management devices to the back-end server
4. All buses equipped with a fleet management devices, tracking the location in a real-time and communicating with the back-end cloud platform via secure channel
5. The back-end cloud platform providing the core functionality of the system including communication, routing calculation, AR content generation and handling, web server and associated web applications
6. Web portals providing secure access to the system for the Novi Sad public transport company, JGSP and other stakeholders for the report generation purposes, creation of the AR content, and the bus stops management (i.e. location).

Commuters (users) will be able through use of their smart phones with installed dedicated mobile application and the AR markers (image or location-based) at bus stops to find out the bus arrival times, and also request the information about the best route to a specified destination. The best route will be devised taking into account user specified criteria such as shortest, quickest and cheapest. Figure 7 shows the AR view of a bus stop equipped with the QR code showing the bus arrival times to the bus stop. Furthermore, the commuters will be able to browse the tourist landmarks around the bus stop (by utilizing the current GPS location if approved by the commuter).

Figure 7. User experience when using the AR smartphone application

Top-level architecture of the proposed system is shown in Figure 8 indicating the main components comprising a smartphone, cloud infrastructure and fleet management devices. The architectural model conforms to the generic IoT reference model such as the one developed within the IoT-A initiative (IoT-A 2010). This model aims to create the architectural foundation of the future IoT, allowing seamless integration of heterogeneous IoT technologies (e.g. fleet management devices, mobile phones) into a coherent architecture.

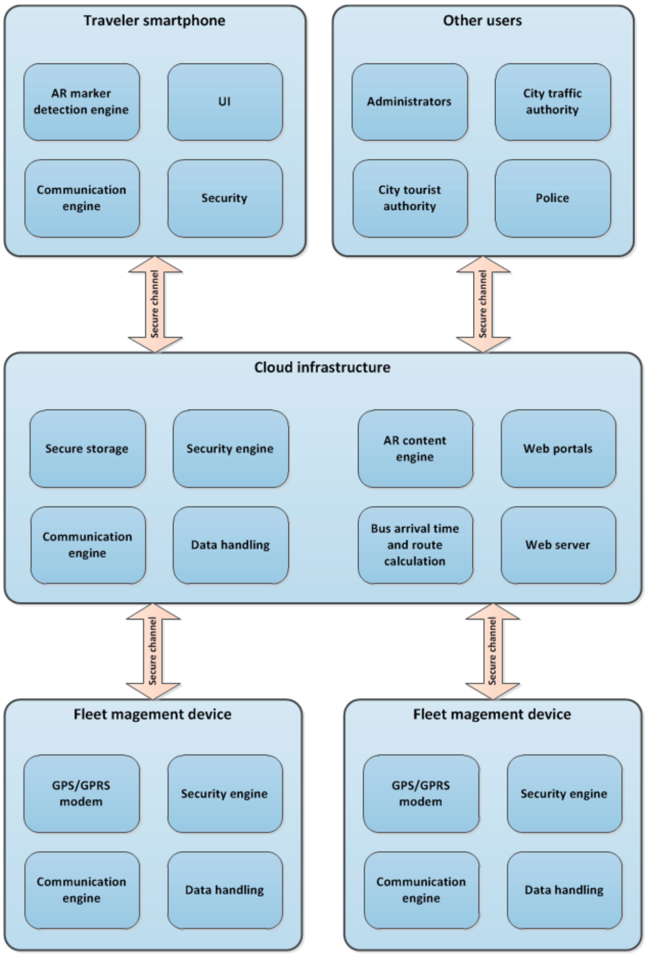

Figure 8. busNET service architecture

The smartphone AR application is implemented on Android platform, but it will also be available for the iOS in the future. The AR marker detection engine is based on Qualcomm's Vuforia SDK (Qualcomm) which is used to process live video stream acquired by the smartphone's camera. The SDK is integrated within the mobile application and used for the detection of the AR marker, currently in the form of QR code placed at the bus stop (see Figure 7. User experience when using the AR smartphone application7). The AR SDK provides information on frame-to-frame basis on which AR marker is identified in the field of view and its location so that appropriate AR content can be rendered. Furthermore, since marker position is detected within every captured frame, smooth tracking and resulting AR content overlay is performed. Alternatively, the location-based marker can be defined so that once the traveller is at the certain location (and within specified radius), AR information is displayed. Once the marker (image or location-based) is detected, an appropriate UI is used to present all the information to the user such as bus arrival times enabling the route selection based on different criteria, tourist landmark browsing and other functionality. Communication with the cloud infrastructure, utilizing appropriate web services, is performed using the communication engine. The security aspects of the smartphone application such as user authentication, encryption and decryption are implemented through the security component.

Cloud infrastructure contains all the core security components (i.e. secure storage and security engine) and these are described in more detail in the section below. Communication engine is in charge of communication with smartphone clients, fleet management devices and other users of the system via secure channels. Access to the AR content (i.e. bus arrival times, tourist landmark data) is provided by the AR content engine. This component also enables the public transport company and city authorities to create dynamic AR content that can be presented to the users. Component dedicated to bus arrival time and route calculation is utilizing the data from the fleet management devices and travellers routing plans respectively. Bus arrival times are calculated using the real-time bus locations, distance to the bus stop, current estimate of the traffic conditions as well as previous knowledge about arrival times at certain time of the day. In order to allow other users of the system (i.e. city authorities, police) to access the cloud infrastructure, web server and appropriate web applications (web portals) are implemented and deployed.

The core component of the fleet management device is the GPS/GPRS modem which is used to provide GPS location and communication link to the GSM network operator. The embedded microcontroller and flash memory provide the limited processing capabilities which are used in executing the program code. The security engine component provides lightweight encryption and decryption algorithms in order to ensure secure data transmission to the cloud infrastructure via communication engine. All the data processing, local storage, parsing and packing tasks are performed within the data handling component.

4. Conclusion

Two smart city services have been developed by DunavNET, aiming to address two very important aspects which greatly affect the quality of life in the city, namely air quality and public transportation. Both systems have been developed in line with the current trends within IoT community utilising the ARM and open standard protocols. The core of the products has evolved from the research activities within the FP7 and CIP projects (SMARTIE, MobiWallet and CITI-SENSE) as well as commercial activities of the company. The services are being deployed within the pilot work packages of the associated projects which has attracted significant attention from the business community. This has resulted in a number of additional commercial installations that are currently being addressed.

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- MobiWallet CIP project, grant agreement 621027, Area of activity CIP-ICT-PSP-2013-7, Period: 1st February 2014 to 31st July 2016.

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Users context-aware

The GAMBAS Middleware for Smart City Applications

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ABSTRACT : *The concept of smart cities envisions IoT services that provide distraction-free support for citizens. To realize this vision, the services must adapt to the citizens' situations, behaviors and intents. This requires them to gather and process the context of their users. Mobile devices provide a promising basis for determining context in an automated manner on a large scale. However, despite the wide availability of mobile platforms, there are only few examples of smart city applications. One reason for this is that existing software platforms only provide limited support for common high-level tasks such as efficient data acquisition, secure and privacy- preserving data distribution or interoperable data integration. As shown by the Bus Navigator – a mobile transport application that has been deployed in the city of Madrid – the GAMBAS middleware can flexibly support such tasks and thus, reduce the development effort for a broad spectrum of smart city applications.*

KEYWORDS: *IoT, middleware, smart city, context acquisition, semantic data models*

1. Introduction

With the advent of powerful mobile devices an increasing number of people have constant access to information on the Internet. Nowadays, these devices are causing a drastic paradigm shift in the way people deal with information. Yet, the technical means to access information have only changed marginally. In most cases, information is accessed via the web which requires persons to memorize long URLs, click through web pages or browse through search results. In contrast, the concept of smart cities envisions IoT services providing distraction-free support. To realize this vision, the services themselves must adapt to the user's situation, behavior and intents at runtime. This requires services to gather and process the user's context.

Mobile devices provide a promising basis for determining user context in an auto- mated manner on a large scale. The vision of smart cities, however, extends beyond the boundaries of a single service as many city-wide applications will require the coopera- tion between multiple data providers and the citizens to exploit their full potential. As a consequence, developers that create applications for smart city settings are facing a broad range of challenges that are typically not addressed by widely available mobile platforms such as Android or iOS. Since these platforms primarily focus on low-level resource management, they only provide limited support for high-level tasks such as efficient data acquisition, secure and privacy-preserving data distribution or interop- erable data integration. As a result, application developers must manually tackle the resulting challenges.

The GAMBAS middlware with its associated software development kit (SDK) ad- dresses these challenges by simplifying these high-level tasks by means of a) models and infrastructures that support the interoperable representation and city-wide pro- cessing of (context) information, b) frameworks and methods to enable resource- efficient data acquisition using the mobile devices carried by the citizens, and c) pro- tocols and tools to derive, generalize, and enforce privacy-policies allowing citizens to control the sharing of their information. In the following, we describe the GAMBAS middlware and its SDK in more detail and we describe the Bus Navigator – a mobile transport application for the public bus network in the city of Madrid that has been developed and deployed successfully.

2. Smart Cities

GAMBAS envisions a smart city as a cloud of intelligent digital services that pro- vides adaptive and dynamic information to citizens. Conceptually, these services and their data can be grouped into so-called layers that cover different aspects of people's life in the city. A shopping layer might encompass services that manage store lo- cations and experience reports on different stores. Similarly, a mobility layer might encompass services that manage bus routes, subway stations, or traffic information. A social layer might manage relationships between citizens, events that take place in the city, etc. An environmental layer might manage information related to water or air quality in the city or it might capture the noise levels at different places. C l e a r l y, some of the services found in these layers can apply to multiple layers as some pieces of information and some of the services might be applicable to multiple aspects.

To enable the creation of dynamic mash-ups of services, the services export (parts of) their information. Thereby, the information is represented using an interoperable data representation that allows automatic linking of different pieces of information. This makes the information accessible to other services which can then add additional value by providing, for example, a better experience for a specific group of citizens. In order to simplify the integration of services, a distributed query processing system enables the execution of queries across different information sources.

For providing up-to-date information and adaptive information to users, the layers capture information from different sensors embedded in various Internet-connected objects. Thereby, the objects may belong either to a particular service provider or they may belong to a citizen. The devices in the first category, may, for example, encompass sensors embedded in a taxi or a bus or they may be deployed at specific positions such as a bus stop or a metro station. The devices in the second category may encompass the personal mobile devices of the citizens such as their smart phones but they also may contain traditional systems such as their desktops at home, for example.

To protect the privacy of the citizens, they can control the collection and sharing of data with services in different layers. Towards this end, behavioral data is stored and processed on the devices that belong to the citizen. Optionally, in order to access additional services, they may share their information with specific service providers or other citizens. In order to avoid the expensive task of manually controlling the shar- ing process, automatic proposals for different settings can be computed automatically based on social relationships that are formalized by means of existing policies that the citizens created for similar contexts.

As a consequence, developers of applications in the smart city domain will typ- ically face the following three challenges. First, to provide up-to-date information in an adaptive manner, applications must be able to acquire (parts of) the context of the citizens using the mobile devices of the citizens. As mobile devices are typically battery powered, the acquisition of data must be resource-efficient. Second, to en- able services to leverage the acquired data, it must be shared. Intuitively, this sharing must be performed securely and it must respect the user-specific privacy requirements. Third, to enable devices and services to interact with each other, they must establish a common understanding of their respective data such that it can be linked to each other in an interoperable and extensible manner. Our GAMBAS middleware provides the tools to simplify these tasks, as described next.

3. GAMBAS Middleware

In the following, we describe the different components of the GAMBAS middle- ware and detail how they support data acquisition, data distribution and data integration.

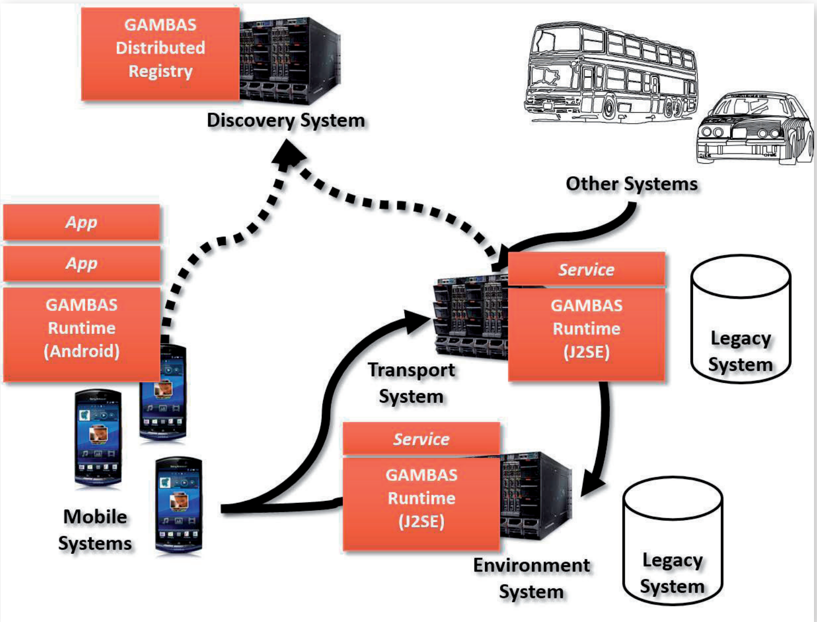

Figure 1. GAMBAS System Architecture

Figure 1 shows the overall system architecture. Conceptually, a GAMBAS deployment consists of different systems. The mobile systems of the citizens are act- ing as both data sources and data sinks. The city systems from different layers are managing data and providing services to the mobile systems. To do this, they may rely on information provided by other services as well as data provided by the mobile systems. Furthermore, they may integrate data from legacy systems and they may be receiving data from other systems through existing means. For example, a transport system might already be collecting information through sensors deployed in a city or in vehicles. Similarly, it may already have access to geographic data describing the different roads in the city.

Intuitively, it is impractical to assume that the existing systems and data sources are likely to be replaced by any middleware. Instead, GAMBAS embraces existing systems and provides ways to simplify the sharing of the information hosted by them. To do this, the GAMBAS middleware introduces three system components, namely the distributed registry, the Android runtime and the J2SE runtime. In the following, we briefly outline their functions. Targeted at mobile devices, the *Android runtime* enables developers to acquire data using the built-in sensors. Furthermore, it allows secure sharing of data with services while enforcing the privacy requirements of the user. Finally, it simplifies the dynamic retrieval of data provided by services. Targeted at systems that provide services, the *J2SE runtime* enables application developers to capture data provided by mobile devices and to offer service-specific data in a way that enables dynamic discovery and simplifies linking. Finally, to support dynamic in- teraction, the *distributed registry* enables mobile devices and services to publish meta data. This enables devices and services to find each other and to establish commu- nication channels. The Android and the J2SE runtime are the core subsystems that application developers interact with. In contrast to this, the distributed registry is pro- viding the glue in order to enable interaction. For the sake of brevity, we focus our following descriptions on the different runtime systems. To avoid repetitions, we first discuss the individual components. Thereafter, we discuss how they are integrated in the Android and the J2SE runtime.

3.1. Runtime Components

Conceptually, the runtime system consists of four main components, namely com- munication, data acquisition, data processing and privacy and security.

3.1.1. Communication

To enable communication between different devices using different technolo- gies, the GAMBAS runtime system relies on the BASE communication middleware (Handte *et al.,* 2010b). BASE enables the spontaneous interaction between different devices, while supporting many communication technologies through a plug-in archi- tecture. Additionally, BASE bridges between different communication technologies, whenever necessary. Using a gateway that is integrated into the distributed registry, BASE is able to establish communication channels, even if devices are behind a cor- porate firewall or a NAT router - which is commonly the case in mobile or home networks. In addition to communication, BASE provides a simple service abstraction which is used by GAMBAS to export system services that are used, for example, to execute distributed queries over the data provided by services or to establish secret keys. From an application developer's perspective, however, the GAMBAS runtime hides all details related to communication and BASE. Consequently, we would like to refer to (Handte *et al.,* 2010b) for more details on BASE.

3.1.2. Data Acquisition

Besides from communication, another capability of the GAMBAS runtime is its ability to capture data on behalf of the user or a service provider. For this it encom- passes a data acquisition component that is capable of running on different devices. Internally, the data acquisition component is using the NARF activity recognition framework (Handte *et al.,* 2010a). NARF is a component-based, extensible activ- ity recognition framework that integrates with different types of physical sensors such as an accelerometer or GPS as well as with virtual sensors such as the user's calendar, for example. It provides an existing toolkit of reusable components such as preprocessors in the time and frequency domain, classifiers, etc. Furthermore, it has been used to build various context recognition applications. When multiple context recognition applications are executed simultaneously on a single device, NARF optimizes the data acquisition with respect to energy consumption by removing redundant sampling and redundant computation (Iqbal *et al.,* 2012). Using a visual editor that is integrated into the Eclipse development environment, an application developer can compose compo- nent configurations via drag-and-drop to recognize a particular piece of context. Once the composition is completed, the developer can export the configuration into Java code that can be interpreted and executed by the data acquisition component.

3.1.3. Data Processing

To store and manage data of services as well as data generated by devices, the GAMBAS runtime encompasses a data processing component. Internally, the data processing component itself is structured in three sub-components that (a) store the data, (b) query for data and (c) discover data. To store the data of the user on a lo- cal device or remotely at a particular service, the runtime uses a semantic data storage (SDS) component. Similar to the data acquisition component, the SDS is primarily tar- geted at resource-constrained devices. The data that is stored in the SDS component follows the linked data principles (Bizer *et al.,* 2009) and makes use of interoperable data representations, storing data using RDF (RDF Working Group, 2004). Further- more, the data storage is able to interface with different types of query processors, depending on the resources available on the device. To make the data stored in the SDSs available to services and applications, two types of query processor components are used. The query processors are capable of executing queries on top of the storages. As query language, SPARQL (RDF Data Access Working Group, 2008) is used. Since SPARQL queries can be heavyweight, on resource-constrained environments such as smart phones, queries are executed using RDF-on-the-go (Le-Phuoc *et al.,* 2010). It is compatible to other, full-fledged semantic web frameworks like Jena (Apache Jena project team, 2013), but runs on Android devices. To enable transparent distributed query processing, the query processors must be able to discover the data sources that are available on the network. To make the data discoverable, a device may announce the data available in the SDS to the data discovery registry which in turn will typi- cally use a semantic data storage component to manage the announcements. In case of personal devices, the announcement may be limited or modified depending on the privacy preferences of a certain end user. To enable this, the semantic data storage and the data discovery registry are interfacing with the privacy and security component.

3.1.4. Privacy and Security

As some data processed within smart city applications, such as the user location, might be sensitive from a privacy perspective, it is necessary to limit the data acqui- sition and the data sharing such that it respects the privacy preferences of different entities. Achieving this is the primary task of the privacy and security component. The component interacts with the SDS as well as the data acquisition component that is deployed on each personal device over a privacy manager interface. In addition, the privacy and security component may also be used to limit the access to information that is provided by a particular service. For this, it is integrated into the device that is offering the service. Using a privacy policy that can be generated automatically by means of plug-ins that access proprietary data sources, the privacy and security component takes care of exporting sensitive data in a way that it can only be accessed by legitimate entities. Furthermore, depending on the user preferences, it may apply obfuscation in order to limit the data precision and it may anonymize the data in order to unlink the data from a particular user. Envisioning the use of mobile devices as primary sources of data, the privacy and security component is supporting not only traditional laptops and PCs, but also resource-constrained devices as its execution platform. In the runtime system, the privacy and security component is divided into a key-exchange mechanism, policy-based access control and encryption protocols.

3.2. Runtime Integration

As depicted in Figure 2, the integration of the components of the runtime sys- tem described previously is realized by: (1) a set of interfaces, support libraries and tools called the software development kit (SDK), and (2) the GAMBAS CoreService which provides the accompanying runtime environment. The SDK in turn consists of two parts. The service programming interface (SPI) is used to develop middleware functions. The application programming interface (API) is used to develop GAMBAS apps. The CoreService sets up the GAMBAS runtime and manages the lifecycle of runtime components. Furthermore, the CoreService realizes the SPI by linking each component to all other components that they use in their own execution via interfaces from the SPI. This effectively provides a tight and efficient integration between the components without inducing dependencies to their actual implementation. Finally, the CoreService implements the GAMBAS API towards GAMBAS applications both on Android and J2SE platforms. It receives calls, forwards them to the right compo- nent and delivers results back to the original caller.

The J2SE version of the runtime system specializes and implements the generic middleware architecture described before for server systems running J2SE. This al- lows service providers to integrate their services into the GAMBAS platform. The J2SE version of the runtime system is implemented as a library that is linked to an ap- plication using it. To start using the middleware, an application has to first import and instantiate the CoreService. To use functionality of the GAMBAS middleware, e.g. to store data, applications can call a number of methods on the CoreService. The Core- Service in turn forwards this request to the corresponding local system component, retrieves results from it and forwards them to the calling application. On Android the runtime system is realized as a stand-alone Android app instead of a linkable library. This design allows us to efficiently share a single instance between all 3rd party apps, reducing the needed resources and thus allowing the OS to keep more apps active in memory for a longer time. As a side effect, direct calls are no longer possible. Instead, we use Android intents which are small messages that a process can publish and that can be received by other processes. The user interface of the middleware application enables the user to configure a multitude of aspects such as the used data discovery registry and communication gateway, the user's pseudonym, known friends, their keysand privacy policies. This allows users to inspect and adapt the current system state in one integrated place and makes it easier for them to understand what data is currently made available to whom.

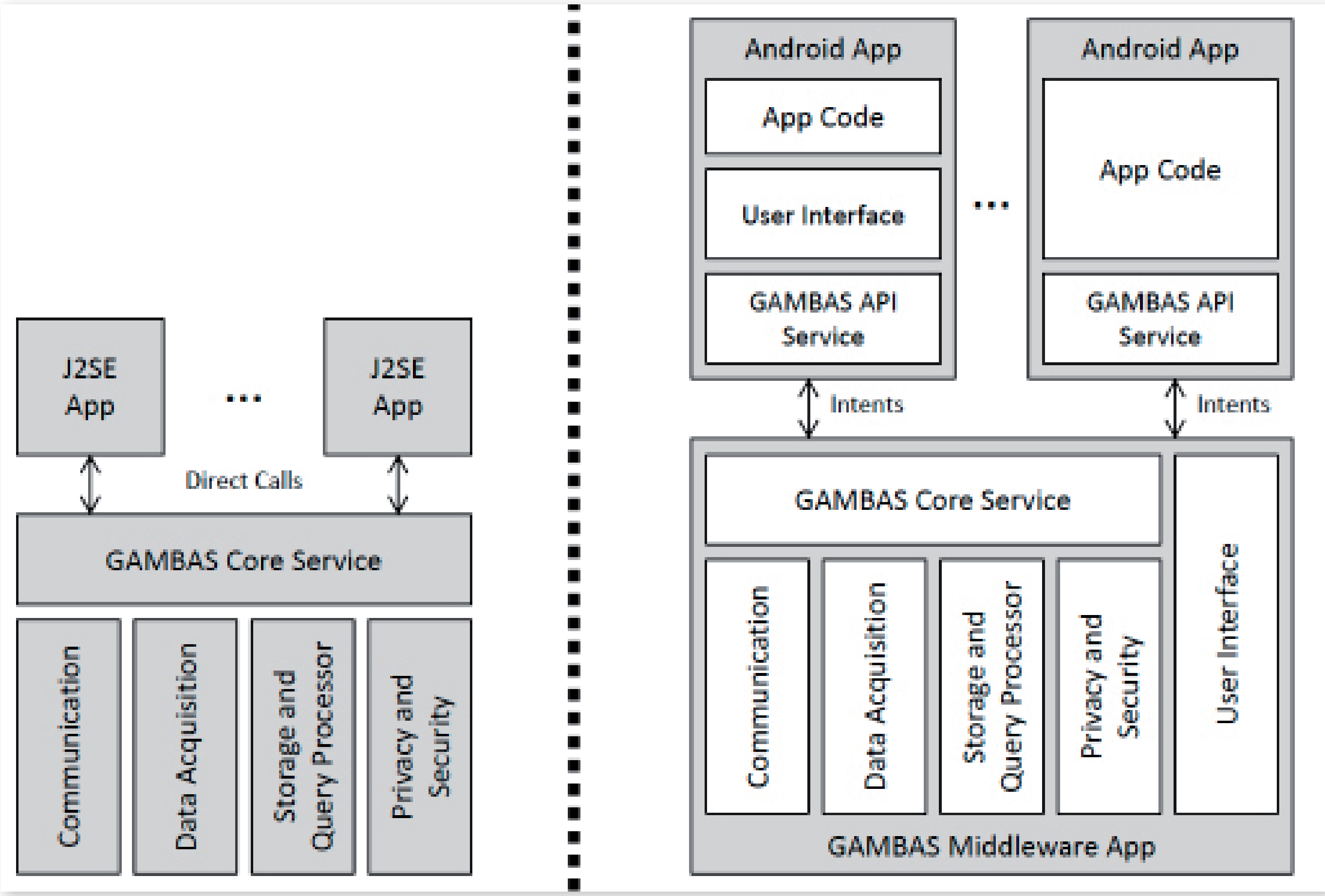

Figure 2. GAMBAS Runtime System for J2SE (left) and Android (right)

4- Mobile Transport Application

The Bus Navigator (c.f. Figure 3) is a mobile transport application prototype for the public bus system in the city of Madrid. It represents one of the two proto- type applications used to validate the GAMBAS middleware and it has been deployed and tested successfully for several months in Madrid. As a common feature of mo- bile transport applications, the Bus Navigator provides up-to-date information on bus schedules and routes. In contrast to existing applications, however, the Bus Naviga- tor provides several innovative and powerful features built on top of the capabilities provided by the GAMBAS middleware to help travelers find their way through large, city-scale transport networks. Most importantly, the Bus Navigator is designed as a continuous navigation service that can take advantage of the sensors built into the smart phones carried by travelers. These sensors capture context and activity informa- tion, which is then interpreted and processed on the smart phone to provide and update real-time transport information relevant to the traveler's current transport behaviour. The key features enabled by the GAMBAS middleware include responsive and pre- cise speech input, advanced trip tracking and information visualization as well as bus ride detection and crowd-level estimation bundled into interoperable behavior-driven services provided by GAMBAS.

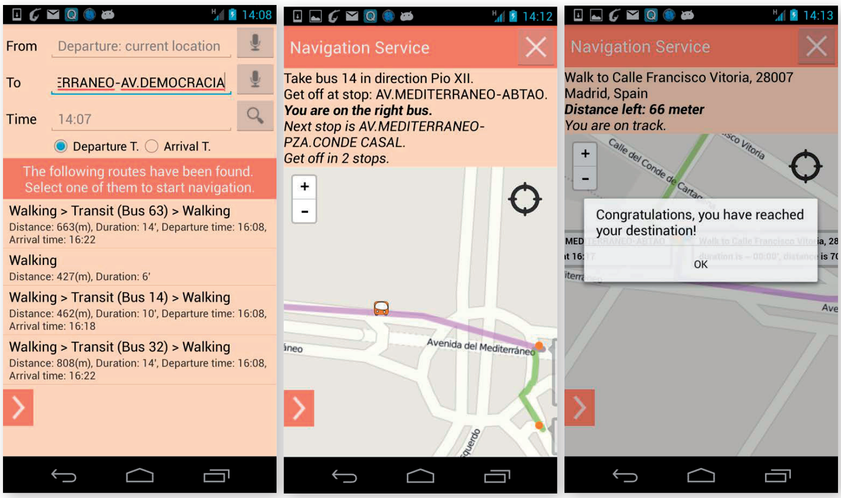

Figure 3. Bus Navigator for the Public Bus Network of Madrid

To support bus detection and trip tracking, the bus navigator ties into the Wifi access points that are already deployed in the buses and provide Internet connectivity to the travelers. Using this deployment, advanced algorithms running on the smart phone determine autonomously when the travelers enter and leave a bus – even if they are not connected to the access points. This enables the application to display relevant information such as the next bus stop, the number of remaining bus stops on the traveler's current route or the fact that the traveler has accidentally missed the stop. When a bus ride has been completed by the traveler, it is stored locally on the smart phone in a SDS. The resulting history of bus rides is used to determine the regular trips made by the traveler, thereby, enabling the automatic prediction of future trip destinations. If a future destination cannot be predicted, travelers can configure voice commands to speed up and optimize the interaction with the Bus Navigator – resulting in a more efficient and more enjoyable user experience. Besides enabling bus detection, the Wifi access points in the buses are also able to determine the number of passengers in the bus. This crowd-level information is collected and anonymized on the access point and transmitted to a remotely located SDS. To the benefit of the travelers, the information is aggregated and displayed as part of the routing data. This enables travelers not only to optimize their trips with respect to timing but also with respect to comfort. In addition, the bus operator may use this information to dispatch additional buses and to optimize the bus network schedules.

5 -Conclusions

Despite the wide availability of versatile programmable mobile platforms, there are only few examples of smart city applications. One reason for this is that existing software platforms primarily focus on low-level resource management which requires application developers to repeatedly tackle high-level tasks. The GAMBAS middle-ware simplifies the development of smart city applications focusing on three common tasks, namely efficient data acquisition, secure and privacy-preserving data distribu-tion as well as interoperable data integration. As indicated by the Bus Navigator ap- plication, with the current implementation of the GAMBAS middleware, it is possible to develop and successfully deploy a smart city application in the transport domain. As a next step, we are working on extending this application to encompass several additional domains such as environmental monitoring and social activities. Towards this end, we are refining the data models and optimizing the middleware performance with respect to data acquisition and data processing. More details on the GAMBAS middleware, SDK and applications can be found at *http://www.gambas-ict.eu*.

Acknowledgment

This work is supported by UBICITEC e.V. (European Center for Ubiquitous Technologies and Smart Cities) and GAMBAS (Generic Adaptive Middleware for Behavior-driven Autonomous Services) funded by the European Commission under FP7 with contract FP7-2011-7-287661. The authors would like to thank the remain- ing members of the GAMBAS consortium for their work on and support for this paper.

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De-verticalization

Industrial M2M pain points: The need for common platforms addressing the needs of multiple verticals

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Abstract: *All main M2M segments and applications suffer from fragmented pieces of technologies and very verticalized platforms. In order to maximize interoperability, cost efficiency, reliability and usability, it is a necessity to bring to the market solutions and enablers which may address seamlessly many segments and types of use cases. This has consequences on the connectivity tools, the information systems managing the life cycles of machines, SIM cards and generated data.*

1- Issues and challenges:

Most M2M deployments suffer from fragmented technologies needing custom integration, lack of end-to-end and efficient control over their systems and systems' life cycle and poor quality of service assurance.

2- The solution

The observation of pain points encountered by professionals from different M2M markets resulted in the elaboration of a solution that would be adapted to their industries' specific requirements. Most commonly, the issues they were facing were:

- Mobile operators' grey and black coverage areas
- Unsatisfactory data service availability rates
- Visited network selection on cost criteria and not on QoS optimization
- Lack of tariff flexibility for M2M connectivity : international roaming fares, bundle offers ...
- Lack of visibility on 2G / 3G continuity over time
- Lack of control over fleet and device life cycles
- Lack of connectivity hooks for smart information systems
- Managing heterogeneous SIM card providers

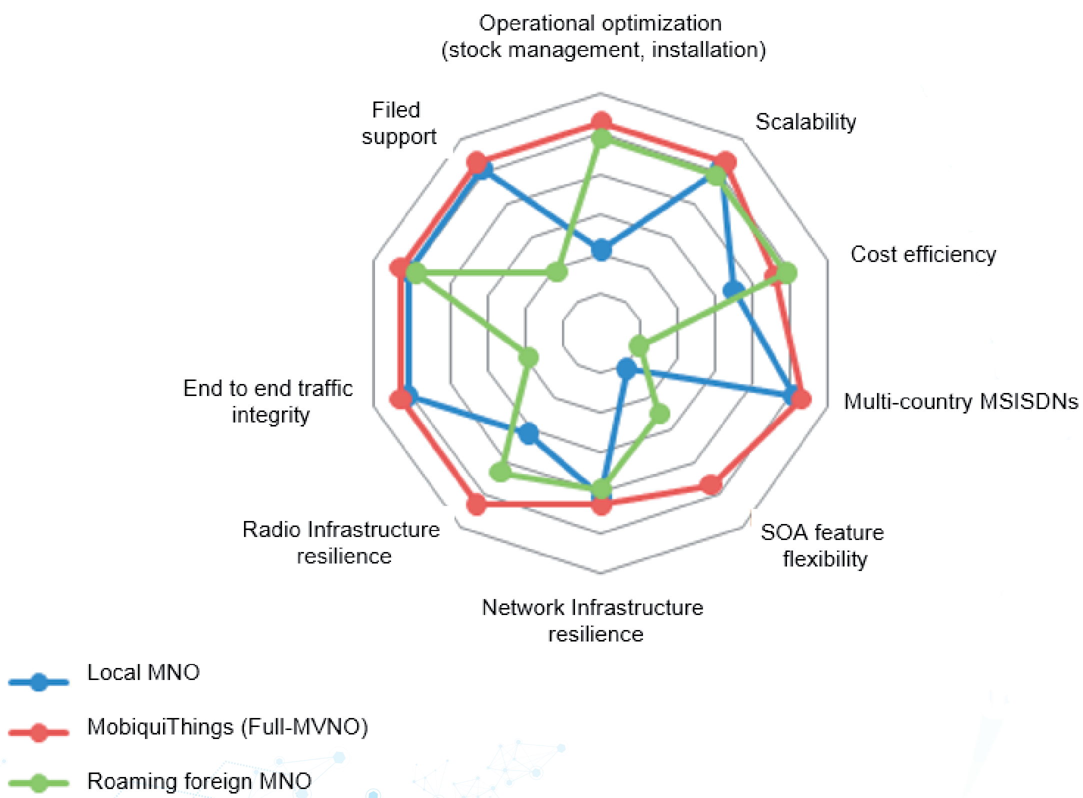
To address these issues, Cyril Hullin, Frederic Maro and their team developed a smart steering on-SIM applet that enables the SIM card to select the best available network in terms of quality of service at any given time. Thanks to its dynamic network attachment, the SIM card can thus attach dynamically to the best giving network according to the operational or business logic of the object/machine, the main selection factors being signal strength and data service availability.

At the centre of our value proposition:

- Quality of service: Our SIM cards dynamically connect to the best giving network based on technical criteria to guarantee the best quality of service.
- Customized solutions: We have a global support team of experts on modems, on-SIM developments, information systems and network architecture, who accompany customers on technical choices to optimize their operations, costs and efficiency.
- Service continuity: Our solution offers service continuity wherever our customers expand their activity, guaranteeing they will have the best coverage and quality of service, and the best availability rates.
- Easy fleet management: Our Network and Information System APIs ensure end to end SIM and Device Life Cycle Management (from provisioning to decommissioning).
- Reduced operational TCO: The MobiquiThings multi-operator coverage helps avoid installation, deployment and logistics complexity with a single SIM for all networks.
- Technology continuity: The technology developed in our SIM cards allows us to offer a technology continuity that mitigates the risk of 2G / 3G mobile network phase-out during the life cycle of the M2M device. In case of an operator's 2G network closure, we will therefore be able to continue supporting this technology until each and every operator has ceased to provide it.

MobiquiThings	Traditional Telcos	Customer Benefits
• Multi-operator • Dynamic network selection: Smart Steering • Best network selected based on technical / QoS criteria • GPRS availability/loss detection and network switch-over • M2M enabling services: Network and Information System free APIs and Web services (SOAP Services Oriented Architecture	• Operation on own network in domestic mode • Static list of preferred (partner) networks in roaming (economical criteria arbitration only) • Roaming SIM = location update based on voice availability • No GPRS loss detection • Simple self-care Extranet with poor or APIs if any	• Maximised coverage • Always connected on the best network • Network attachment according to the fleet's specifics and business logic (data, most of time) • The SIM card is always able to communicate • Easy fleet management

MobiquiThings compared to traditional MNOs:



3-M2M applications

Our customers (Utilities, transportation, retail, security, healthcare, or industry players) are working in various domains with very specific needs, and different stakes. This is why we designed our solution with the constraints of their activities in mind.

	UTILITIES	TRANSPORTATION	RETAIL	SECURITY	HEALTHCARE	INDUSTRY
Applications	Smart metering (automated meter reading) in electricity, water, gas turbines, wind & solar farms, generators... smart grid monitoring & metering, remote asset tracking & management	Location based services, maintenance records, toll payment, navigation, Eco driving assistance & incentive, fleet & asset management, vehicle telematics, theft prevention & recovery	POS payments, ATM, vending machines, advertising (digital signage), customer/ passenger information, goods tracking	Video surveillance (CCTV), home security (alarms), fire security, SCADA, metering, prisoner monitoring	Remote patient monitoring, drug tracking, asset tracking, remote workers safety, telehealth	Telemetry (probes, meters, alarms, pumps, valves ...), asset tracking (assembly lines, gas tanks, logistics, ...), complex facility management & security, dangerous area monitoring
M2M benefits	Virtuous consumption incentives, reduced waste & consumer bills, production load balancing	Improved asset use, improved tracking information, reduced cost of ownership	Quicker transactions, contextual mediation, refrigeration monitoring, shelf space optimisation	Increased safety & security, alert management, lower TCO with improved efficiency	Improved asset use, transportation savings, fraud detection, improved patient comfort	Improved cost of plant management, alert management, security improvement, improved supply chain
MobiquiThings Value Proposition	Enhanced radio network coverage & QoS (urban & rural), flexible TCO over time, embedded soldered SIM, device life cycle management	Enhanced coverage (rural, urban & cross borders), cross border TCO reduction, reinforced embedded soldered SIM reducing fraud risk, vibration & extreme temperature issues	Improved coverage (urban mainly), enhanced connectivity, TCO reduction over time, payment device life cycle management over time	Improved coverage (rural & urban), enhanced connectivity TCO over time, embedded soldered SIM	Improved coverage (rural & urban) and QoS, device life cycle management across geographies	Improved coverage (rural & urban), flexible TCO over time, embedded soldered SIM, device life cycle management

4- Use cases / examples

4.1 Utilities/energy

Homerider

Homerider Systems, a division of Veolia Water, has selected MobiquiThings for metering solutions deployments. (Fuel tank monitoring, water metering...)

"MobiquiThings' technology enables Homerider Systems to offer a service continuity and quality of service to its customers: "radio smart and dynamic steering, as well as bearer steering enable to adapt to the criticity of the data to transmit." explains Homerider's head of Industry Business Unit.

AMCS

AMCS Group designs, develops, implements and supports integrated environmental softwares and solutions for the recycling and waste management industry. Their activity focuses on:
- RFID technologies for bin chipping, identification and tracking
- Bin & Container Weighing, FEL Weighing, On-board Vehicle Software and more
- Core customer data, inventory, invoicing, reporting, analysis, web-portals and more

AMCS Group use MobiquiThings' SIM cards and solution for their deployment on the French territory, in order to optimise their solution coverage and reliability.

Intent Technologies

Intent Technologies provides the first operating system dedicated to the applications of smart buildings. The Intent Technologies OS allows every actor of the building ecosystem – operators, providers and occupants – to connect together with their environment through a white-labelled online store for usage data, digital applications and services.
As part of its commercial offer, Intent Technologies designs and develops building instrumentation products shipped with embedded connectivity modules that communicate over-the-air with their online store using the MobiquiThings wireless M2M network. MobiquiThings' dynamic multiple-carrier technology along with a wide international coverage enables Intent Technologies to provide its customers with autonomous, secured and reliable connected solutions at low cost.

Kamstrup

Kamstrup Services France is the subsidiary of KAMSTRUP GROUP. Kamstrup Services develops and offers metering solutions for urban heating.
In order to improve their solution's reliability, Kamstrup proposes various services using mobile data communications (GPRS...). The fields of application are often located in poor radio coverage areas (deep indoor, underground cellars, factories generating strong interferences...). In the past, Kamstrup Services France used several SIM providers to deploy different operators on different locations after local testing campaigns, thus multiplying the constraints, resulting in heterogeneous SIM life cycle management systems. Today, Kamstrup has only one SIM cards fleet to manage in order to maintain a reliable solution.
"For our field operation personnel, there is now no need to lose time in testing the best network at a given place, the SIM selects it automatically. If an access operator meets a problem, with an unavailable network, the SIM switches network automatically and autonomously" explains Kamstrup Services' representative.

4.2 Transportation

Invers GmbH

With projects in 18 countries, Invers supplies car sharing companies and motor pool operations with innovative modular systems consisting of an in-car software technology. Over 40,000 vehicles are operated worldwide with this technology.

As an independent company, Invers is actively involved in creating the future market for car sharing technology, and thanks to MobiquiThings, they only have one SIM cards fleet to manage across the world.

Zenpark

Zenpark offers the first automated shared car park service in France, which allows its customers to access an intelligent network of shared car parks. This is a handy and economical solution that allows its customers to park with confidence. The Zenpark car park network is composed of various partners (hotels, landlords, companies, car park managers, administrative buildings...) who optimise the use of their car park space.

Everything is automated and secured: Zenpark installs an innovative system equipped with a MobiquiThings SIM card at the entrance of the car park, which enables Zenpark's members to access it thanks to their Zenpass or via their mobile phone. Our multi-operator solution provides a good network coverage in these places and insures constant connectivity to Zenpark's members, who can use the service at any time.

Traxens

Traxens innovates to make containers intelligent and to redistribute the information coming from them (position, alerts, and legal happenings) to the stakeholders of the supply chain thanks to the connectivity provided by MobiquiThings.

Working closely with the best actors of the logistics industry, Traxens develops dedicated applications around TRAXed containers. These applications can be accessed through the Internet at competitive rates to enhance productivity, security, as well as the ecological footprint of the shipments.

4.3 Retail

Verifone

Point Transaction Group is a subsidiary of Verifone, the global payment player. Point Transaction is deploying MobiquiThings' solution on the French territories (mainland and overseas) in order to optimise and maximise the quality of service offered to retailers with high expectations in terms of reliability, and in specific mobile transaction scenarios.

BR Gaming

The BR Gaming company has developed the Pan African Africa Million lottery derived from the European model Euromillion in six African countries: Senegal, Gambia, Congo-Kinshasa, the Republic of Congo, the Ivory Coast, and Guinea-Bissau. BR Gaming offers their customers the possibility of choosing their numbers via a mobile terminal equipped with a MobiquiThings SIM card. To do so, the Africa Million representative goes to meet his customers with his mobile terminal. GPRS coverage being very uneven on the African continent, our multi-operator solution with GPRS detection has become a prerequisite to the success of this project.

4.4 Value Added Resellers:

Matooma enables and facilitates logistics, financial and communication flows in order to handle and control more efficiently and transparently SIM cards and objects. They provide some of their clients listed below with MobiquiThings SIM cards under the premium Matoocard branding:

Securitas

The expert in security solutions offers services such as trained security officers performing guarding services, mobile security services, video surveillance, aviation security, and other services and trainings related to security.

Securitas has decided to entrust Matooma and has chosen our multi-operator SIM cards, which ensure maximal coverage and guarantees their assets are always connected, even in the event of a network failure of one of the visited operators.

Vinci Park parking meters

With a strong commitment to urban life, VINCI Park plays an active role in all forms of mobility within the urban environment, innovating to make the city friendlier, easier to use, and more dynamic.

On-street parking is often an integral part of city centre car parking problems. VINCI Park proposes on-street parking solutions optimised for the community. Tailored specifically to each community, this road management reduces congestion in the city, benefiting both businesses and travellers. The company manages 365,400 on-street parking spaces, and 17,300 parking meters on over 1,800km of road.

VINCI Park has put contactless and remote payment systems equipped with multi-operator SIM cards in their parking meters via Matooma to maximise their revenue and the rate of compliance with parking rules, to make the commercial side of parking easier for road users, and to increase the traceability of payments and make the organisation of parking fines easier for the teams dealing with them. With the MobiquiThings SIM cards, the company has only one SIM cards fleet to manage, and they don't need to make coverage pre-tests before installing new meters.

Europ Assistance

Europ Assistance has been the world leader in teleassistance services for about 50 years.

With telemedecine, teleassistance, medical/social coordination, chronic disease monitoring and so on, the Health Care Services draw their power and efficiency from the integration of new technologies. Teleassistance takes the form of an alert device installed at the home of the beneficiary, which is linked to a transmitter (medallion, bracelet or telephone) that the patient is wearing permanently. In case of an end user's faintness, fall, or any other source of worry, this device enables the person to contact Europ'Assistance immediately on a 24/7 basis. 450 000 persons have subscribed to teleassistance services in France. Yet, with the gradual withdrawal of the landline, the multiplication of telecom operators and the persistence of black coverage areas on the territory, the management of operators' activity has become more complex.

Europ Assistance has opted for the simplicity of the Matooma solution consisting of our multi-operator SIM card to address these. Their installers are carrying a unique case that is capable of detecting the four GSM-GPRS networks. Thanks to this, they can work faster and have more time to dedicate to customer relationship. In addition, the security of the device is strengthened, since the SIM card will automatically select another network if a network failure should happen.

Plastic Omnium

Plastic Omnium offers innovative solutions answering citizens' needs, such as waste containerisation, or urban signing and planning. A better waste management contributes to the protection of the environment and to the preservation of the living environment of the community.

Plastic Omnium uses the Matoocard, based on our multi-operator SIM cards for their deployments, in order to optimise the service they offer through enhanced coverage and reliability.

5- The company

MobiquiThings was founded in 2010. The company can be defined as a spin-off of Alcatel-Lucent in the sense that its founders imagined the solution while working for the latter, and that the company was founded with the help of Alcatel-Lucent. While working for Alcatel-Lucent, Cyril Hullin and Frederic Maro identified M2M professionals' pain points when it came to the services offered by generalist mobile operators, and imagined a solution dedicated to these professionals.

MobiquiThings is a global mobile operator and a pure player in M2M connectivity (producing data, voice, SMS, CSD, USSD services). Our strength rests upon our fully redundant mobile core network (split between France and Germany). This technical infrastructure is the cornerstone of our proposition, as are our M2M information system (front back end tools) and "smart steering" on-SIM applet.

The company has deployed in a year and a half over 120k SIM cards for its customers in about 50 countries.

Since we marketed our solution, we've experienced a 25% growth on a monthly basis, and over 60% of our business is related to export.

We are glad to count companies like Thales, Veolia, Verifone (payment terminals) and AMCS Group as well as major value added resellers among our customers. We are also proud to work with innovative start-ups, which focus on subjects we particularly like, such as for example Zenpark's smart car parks.

Data exchange

Device Data eXchange
The Gateway to Real-Time Data

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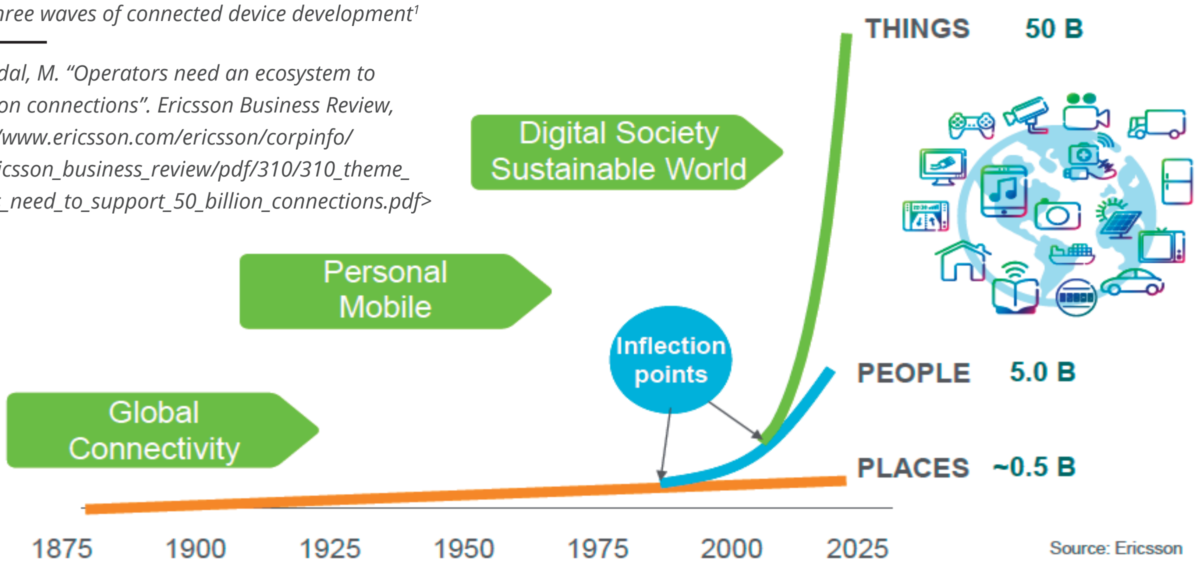
ABSTRACT: *Device Data eXchange (DDX) is a horizontal proposal by Ericsson to create Data Value Chains by setting up a marketplace where (device) data owners can offer real-time data sources and service developers can discover, purchase and use said sources. Although the technical requirements are challenging, it is the business feasibility the touchstone of the proposal. We believe that both data owners and service developers can benefit from the DDX concept. The former by gathering additional revenues and accessing a wider innovation community. The latter, by obtaining data sources and tools to create better services and being able to earn more money. The DDX operator would be the "man-in-the-middle" that leverages its relationships with data owners and provides a charging hub in a similar way to what application stores do.*

KEY WORDS: *marketplace, data exchange, device data, monetization.*

1 -Motivation

The Internet, as we know it today (an Internet of People), is evolving very fast to also encompass the so-called Internet of Things (IoT). In the IoT/M2M scenario, the forecasts predict a tenfold increase in the number of connected devices from 5 billion worldwide in 2010 to 50 billion in 2025 (Figure 1). It means that the amount of real-time data that flows through the networks will get multiplied by several times. The management of this huge amount of real-time information, so that it is possible to make sense of it, becomes one of the main challenges in the IoT/M2M environment.

Figure 1. *The three waves of connected device development*[1]



1 *Alendal, M. "Operators need an ecosystem to support 50 billion connections". Ericsson Business Review, 2010-1, <http://www.ericsson.com/ericsson/corpinfo/publications/ericsson_business_review/pdf/310/310_theme_what_operators_need_to_support_50_billion_connections.pdf>*

There is another key technical issue to address. Real-time information sources (especially when talking about devices) are by nature heterogeneous, often isolated and distributed and, as a consequence, there is currently a low degree of reuse of the information being generated by devices. Services that rely on such device information are few and part of a walled-garden environment.

The second group of challenges relates to the business environment, to how the information is shared, and which new value chains are enabled. An example to describe the barriers that need to be overcome can be provided: Nowadays the wireless market has become global because of the existence of standards and agreements among the telecom operators, but in the IoT/M2M world the situation is much more immature. Although there is a growing effort in creating standards for protocols, sensors, networks, and so on, big challenges remain at organizational and business levels: the big silos of information mentioned previously are isolated, and only consumed within the borders of a company or even a department or a single application.

Business challenges are not only found in the information generation side, but also in the consumption of said information. Parties wishing to enhance their offerings with real-time information (provided that the information is available somewhere in the Internet) need to locate and access suitable information, usually from disparate sources.

The need for creating a marketplace that enables cross-domain aggregation and exchange of M2M/IoT data, is thus compelling. There are additional arguments to acknowledge the abovementioned need and state that this kind of markets will be feasible in the future. One is the success of the so-called Application Stores; another is the availability of real-time sources of information. Related to the apps market, today more than a million applications are available in the Apple iOS and Google Play app stores. About 3.5% (40,000) of these applications use real-time data When it comes to sources of real-time information, business, governments and publicly owned corporations, as well as more and more private users of mobile devices, have spotted the opportunity to share and monetize the data they generate. The Ericsson vision of 50 billion connected devices by 2020 provides a picture of what is expected in the near future with billions of devices generating real-time information and the need of processing this information in order to offer new services to end customers.

The combination of the best of both worlds (Application Stores and Real-Time data sources) will contribute to push forward this M2M/IoT wave beyond its current limits. And a catalyzing factor will be the access, aggregation, and structuring of real-time information flows into a simple and integrated view to service providers and developers, thus enabling them to figure out innovative applications and services based on real-time information.

The areas where access to real-time data can really make a difference are countless. They involve different scenarios of generation and consumption of such type of data, with entities of arbitrary size in each end of the value chain –generation and consumption, even in both at the same time–, and involving models with open or private access to data generated by a given entity. The underlying assumption is that, in the same way as application stores do, access to real-time data can sometimes be charged thus providing incentives for all the parties in the ecosystem. A second assumption is that, as a growing number of real-time data sources are available, more and more innovative services will be created, as a sustainable ecosystem of service developers has appeared.

The value chain (simplified) would comprise several actors (see Figure 2):

- The (device) data owner, which provides device-based real-time data;
- The entity in charge of the aggregation and exposition (exchange) of data sources. It provides the means for data owners to expose their data and enable its use by third parties;
- The service developer that uses real-time data for creating new services and applications;
- The distributor, usually an application store, in charge of selling applications. This role is not always needed as it depends on the specific scenario;
- The end-user, the party that consumes application and services and sometimes pays for them.

These business roles are not exclusive and, depending on the scenario, a same entity can play the role of data exchange and data owner.

Figure 2. DDX data value chain (simplified)

2- The Device Data Exchange (DDX) Concept

Within the FP7 BUTLER project[1] (2011-2014) we have developed the Device Data eXchange (DDX) concept. It aims to enable device data capture, aggregation and exposition. It can be seen as a fundamental enabler of a total IoT/M2M value chain, so that any kind of service provider can get a simple and integrated access to real-time data generated in the IoT ecosystem that enhances their services or enables new ones.

The DDX works as a two-sided platform, interfacing two different business actors, each of them with different needs and pain points. On one hand, owners of M2M devices and other real-time data sources (primarily deployed to support its business needs) can expose such information and therefore get an additional benefit from said data. On the other hand, service providers are offered a single point to find and use data sources, simplified API's for exposed data, critical mass of data sources, means for the discovery of data sources (by feature and/or geographical location, for instance), and the means for handling payment procedures towards data owners. Data owners take the responsibility of sharing their real-time data through the DDX platform and are enabled to manage them by establishing the conditions under which they are exposed. Service providers, though API's, may subscribe to and access real-time data and integrate them into their application and services. Those application and services can, in turn, be distributed through an application store or through private environments.

We believe that, in order to add an extra value to existing and new customers (mainly to those belonging to the service developer category), in the near future it will be necessary to offer all this real-time information in an organized and structured environment allowing the companies to generate innovations based on real-time value added services.

DDX is both the business role and the platform where both trends join, offering for service providers and developers the opportunity to develop innovative applications based on information coming from different and heterogeneous sources of information, and, on the other hand, allowing companies and individuals to monetize their data assets. Figure 3 provides a high level vision of the real-time data flow going from the data sources through a two sided platform to the end user.

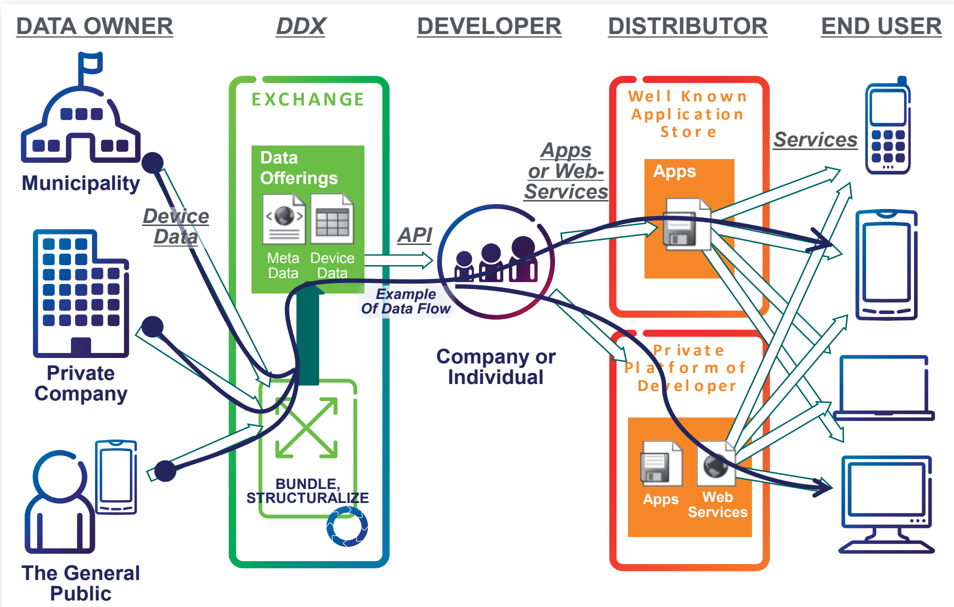


Figure 3. DDX offering to each player

1 *BUTLER (uBiquitous, secUre inTernet-of-things with Location and contEx-awaReness) is an Integrated Project within the FP7-ICT-2011-7 call. See http://www.iot-butler.eu/ for further details*

The DDX concept aims to become a horizontal enabler that bridges the gap between real-time data sources, such as those associated to devices, and the application world. Although the scenarios where DDX is applied and the entities in the value chain may impose different constraints to deployments, the main functionalities associated to DDX remain the same:

- Data Owners are enabled to create and activate real-time data offerings that will be offered to service developers with appropriate service levels. Access to data could be charged depending on the scenario and on data owners' requirements.
- Service Developers will be able be to discover real-time data offerings that match their requirements and subsequently use (and pay if needed) them in the applications and services they create. The offered functionality can be structured in the following levels:
    - Level 0 (Data Distribution): Service Developers are able to use data streams that are provided by data owners (with minimal adaptation, usually only a protocol conversion).
    - Level 1 (Data Mixing): Service Developers are able to combine existing data streams to create new streams.
    - Level 2 (Business Events): Service Developers are able to define triggers over existing data streams and receive notifications when the conditions are met.
    - Level 3 (Data Analytics): Service Developers should be able to order specific analytics tasks on data streams they have previously selected or created (by means of the functionalities in levels 1, Data Mixing, and 2, Business Events). This level us currently out of the scope of BUTLER, although is the straightforward continuation of the currently implemented levels.

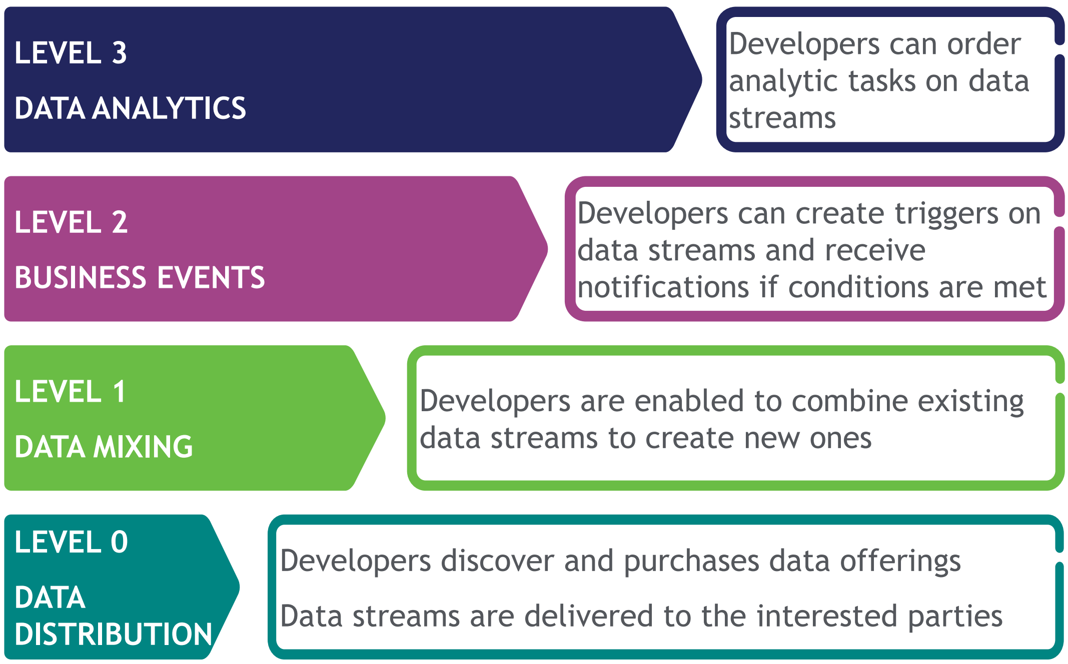


Figure 4. *DDX Offering to Service Developers*

3- Business Model

The DDX business model can be described in a simple way. The figure below shows a simplified value chain (the App Distributor role has been introduced to clarify the way the money flows, but is actually transparent to DDX business model). Revenues flow from the End-Users, who pay for some of the applications they consume. The payment to Service Developers is handled through existing mechanisms (as the ones established by application stores such as Apple AppStore or Google Play; they are not actually relevant to the business model being introduced here). Service Developers pay, using different types of pricing schemas to the DDX operator, which distributes the final payments to Data Providers).

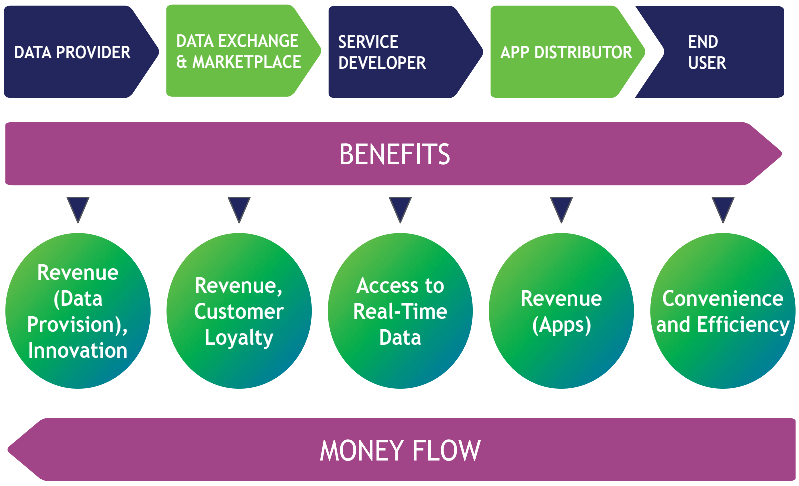


Figure 5. DDX Revenue Flow

DDX business model brings benefits to all the components along its value chain. The incentives for Data Providers are not only tied to the generation of new revenue sources (as the end-users will pay for the services and applications, following the application store business model), but also to the possibility of having innovative solutions built on top of their data (thus creating new solutions that can be useful for them), but can also consider, for instance, the availability of other data sources to add to theirs so that they can create their own business solutions. Service Developers can benefit from accessing a one-stop shop where to find real-time data sources that can be used to build their services.

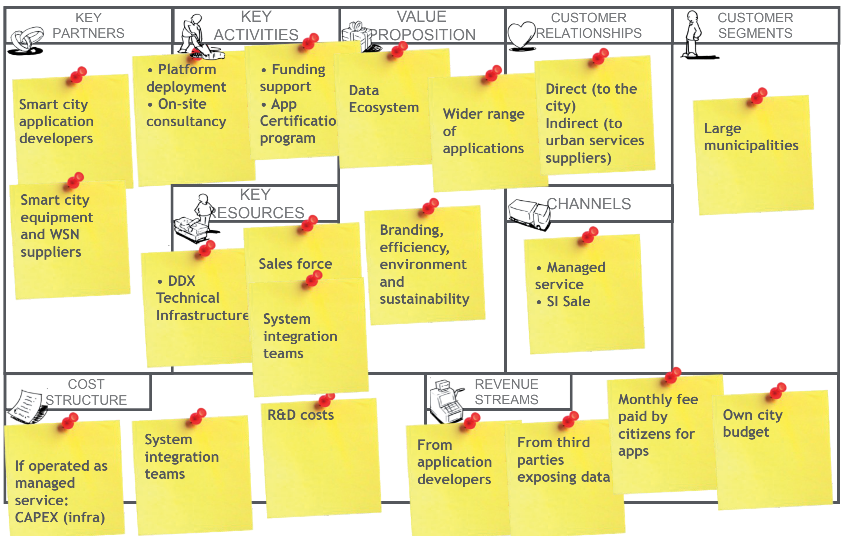


***Figure 6.** DDX for Smart Cities (Business Model Canvas)*

In order to explain some of the business models that this proposal can support, we will provide an example. It describes the business model of a DDX operator that implements an ecosystem associated to a (smart) city. We will use the Business Model Canvas methodology[1]:

Value proposition: DDX provides a market place for smart cities to publish data streams coming from any kind of sources. Such data streams can be used by third-party developers to create applications that provide benefits to citizens and society (easier life, lower energy consumption…). While access to "basic" data streams can be free ("basic" meaning data streams with low transformation or combination, with low update frequency, low precision), funded from a local authority or company, access to advanced data streams is subject to a fee (on one hand "advanced" data streams are those that own special quality with regard to frequency, delivery guarantee and so on; on the other hand, they can be those created as the result of a definition or events by the very Service Developer, or as a combination or basic data streams). Access to data streams is handled according to purchased service levels and data source capabilities. Thus, cities becoming smart:

- are able to create a framework for exposing their own data sources, as a city data hub;
- enhance the range of services received by citizens beyond what the city can actually deliver by creating an ecosystem, since any third party may take advantage of data sources for creating applications;
- enable other parties to include other sources of information (for instance, people counters…)

Customer segments: Cities becoming smart cities. They have made (or are planning to make) a big investment in "wiring" the city, by deploying a wide range of sensors. On the other side, they need to deliver services to their citizens making their lives more convenient, reducing energy consumption and making a city more sustainable, thus proving the investment made has an appropriate (social) return of investment.

- Revenue streams: the city, through DDX, obtains money from three sources:
    - Fees charged to consumers of "advanced" data streams (that is, data streams that come out as the result of the mixing of incoming data streams, the creation of business events or results of analytics tasks);
    - Fee (or commissions) charged to Data Providers using the DDX to expose their data;
    - Own budget.
- Cost structure:
    - DDX platform costs. It depends on the model being offered by the platform supplier. It can be a Managed Service (thus removing the CAPEX) but also a "classical" deployment project. Here CAPEX (infrastructure) is high, especially at the beginning. Operation costs are not negligible at all and must be kept to a minimum.
    - On-site consultancy (analysis of the city situation)
    - System integration costs.
- Key partners:
    - Suppliers of smart city equipment
    - Suppliers of range of pre-tested applications that could be deployed off-the-shelf

1 *The Business Model Canvas is a strategic management template for developing and sharing business models initially proposed by Alexander Osterwalder in 2008. A preview of "Business Model Generation" can be found in http://www.businessmodelgeneration.com/downloads/businessmodelgeneration_preview.pdf*

4- Technical Description

A high-level view of the DDX architecture is shown in Figure 7. In that architectural representation, two different planes are described. On one hand, the Real-Time Data Marketplace provides the means for the users of the DDX services to manage their data sources and the way they are offered (Data Owners); to discover data sources, to define new data streams and events (Service Developers). Management and Discovery of available data sources is based on a map-based interface. From that plane, the appropriate commands are sent to the traffic plane (the Data Management) where different functional blocks are defined:

- Inbound and Outbound interfaces provide the means for the connection of data sources and for applications to access data streams they need. Asynchronous delivery of information is based on Mosquito's MQTT. Once a data offering has been purchased, the Service Developer receives an MQTT client to integrate into their applications. Synchronous access to stored information is provided by means of ad hoc RESTful interfaces.
- A Complex Event Processing (CEP) engine is in charge of distributing data streams, create new ones and implement event functionality. It is based in Apache S4 but other CEP engines could be valid too. Rule injection is supported by jBoss Drools. Drools is integrated in the Service Developer Portal in order to enable Service Developers to combine data streams and create new events.
- Relational storage is used to store the data source information. It is based on PosgreSQL. The PostGIS plug-in is used to provide geographical support.
- NoSQL storage can be provided in order to enable data post-processing and for allowing the caching of information being handled by the platform. We are using MongoDB.

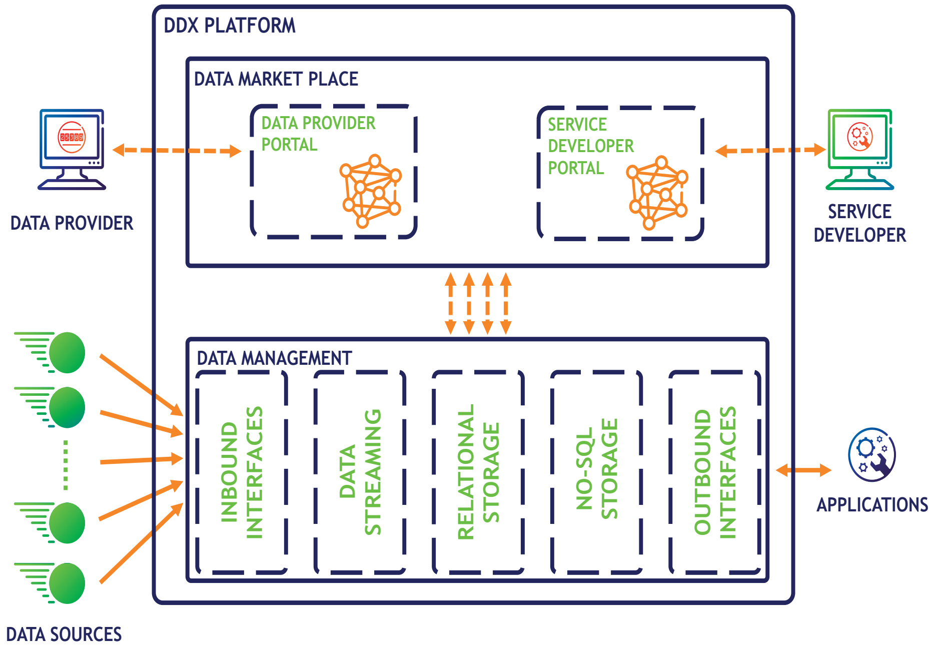


Figure 7. *DDX Architecture*

5- Use cases

The DDX concept aims at becoming a horizontal enabler that bridges the gap between real-time data sources, such as those associated to devices, and the application world. Although the scenarios where DDX is applied and the entities in the value chain may impose different constraints to deployments, the main functionalities associated to DDX remain the same:

- Data Owners are enabled to create and activate real-time data offerings that will be offered to service providers. They do so by picking up the data sources they manage and packaging some of them. Access to data could be charged depending on the scenario and on data owners' requirements.
- Service Providers will be able be to discover real-time data offerings that match their requirements and subsequently use (and pay if needed) them in the applications and services they create.

5.1. Creation of Real-Time Data Offerings

The first activity that must be carried out is guaranteeing the connection of data sources to the DDX. Depending on the type and deployment of devices and other data sources, the procedures to make this connection are different, involving varied integration activities. Once the IP connectivity is achieved, the adaptation of protocols and data models is done by means of software connectors that "plug" data sources into the DDX platform. Basic socket and REST-based interfaces are provided, but integration of any type of dynamic data sources is supported. Once the connection of data sources is achieved, the data owner is provided a web interface, the Device Owner Portal, for the creation and configuration of virtual entities (thus representing entities in the real world), sensors, devices and data offerings comprising the data sources that s/he owns. Data offerings are assigned features which can comprise a service level (the conditions under which the access to the offering will be carried out by service developers: for instance, the maximum number of clients of queries per hour, the sampling frequency, how fresh data is, that is, if the access can be performed in real-time or by accessing a database recording past values of data and so on); a set of descriptors (tags) (each offering can be assigned different tags enabling developers to discover the most suitable offerings according to their requirements; for example, a developer trying to create a weather application for Stockholm would use tags such as "Stockholm" and "temperature"); visibility (public/private); location information; and a price, if wished.

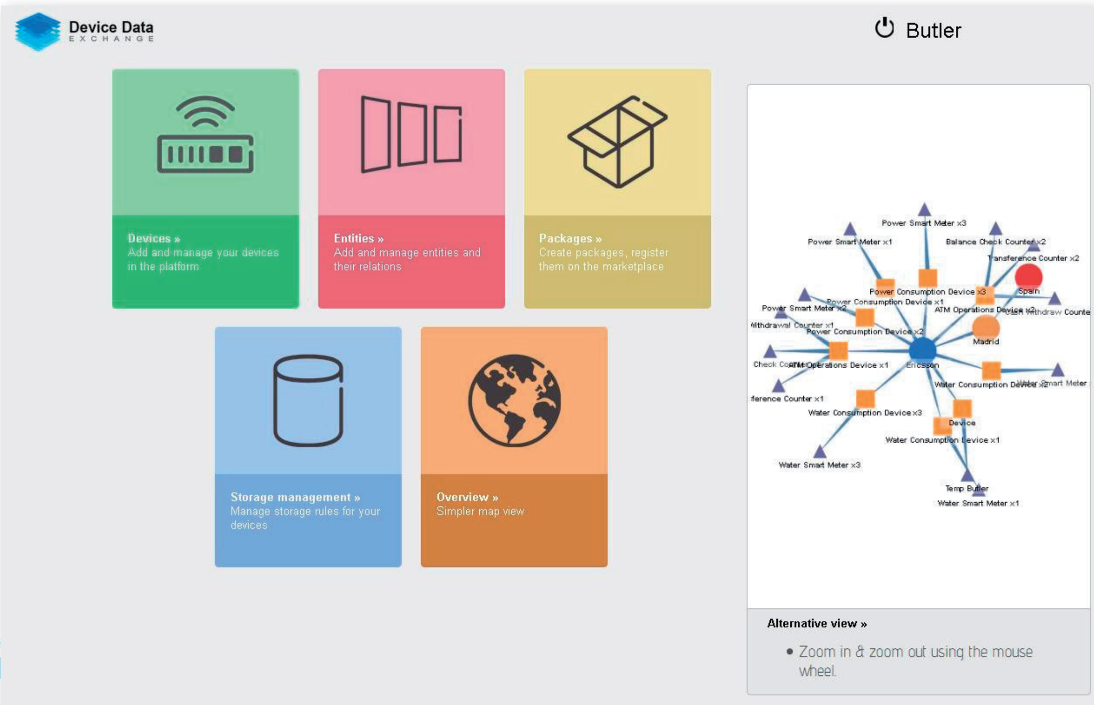


Figure 8. Device Owner Portal main menu

5.2. Discovery of Data Sources

Once activated, data offerings are ready for being discovered, purchased and used by service developers. A typical deployment provides a data marketplace (similar to the role of application store, but this time providing data offerings), the Dynamic Data Mall. Service developers are provided several search options (by tag, by location, by device owner, by price, combination of the aforementioned options...). They can search and purchase the data offerings that better match their requirements, thus receiving the parameters and credentials for further use in their applications.

Service Developers are also enabled to combine different data sources (by purchasing several offerings) and to define events that depend on conditions tied to values of data items in data sources). The Service Developer is provided a simple interface to, by using Drools Rule Language (DRL), define his/her own Business Events.

Upon granting of the use of a data offering, the DDX platform creates the needed configuration to allow subsequent reception of data included in the offering.

Figure 9. Dynamic Data Mall main menu

5.3. Access to Data Offerings

Once the developer has been granted the right to use a data offering, the data included into the offerings are ready for use by service developers. Access to data is done by subscribing to a MQTT broker called Mosquitto. Service Developers are given a JAR file that will be used by the applications to receive data and notifications, the credentials associated to the purchased data offering and sample code to help the developer to integrate the DDX notifications in his/her applications Access to data sources is accounted for subsequent charging and usage analysis.

6- Examples

DDX relies on the same implicit assumption that drives innovation in open data environments: that opening the access to plenty of data sources, service developers will be able to create new value, a value that was not initially foreseen and that was not the initial purpose of the data being collected or generated.

Some examples are provided below. They does not intend to create a specific value in themselves but to illustrate the possibilities of a DDX-like schema.

6.1. Smart City scenario

A very simple example can be extracted from a smart city scenario. In this scenario different entities are enabled to provide real-time information about assets they handle (the municipality, through in-pavement sensors, provides information about available parking spaces on the street; also meteorological information, such as temperature, humidity, pollen levels…; parking lots owners provide the available parking spaces on nearby parking lots; a telecom company reports about the number of people at the street; taxi companies provides the location of free taxi cabs in the area; the public transport consortium offers the location of nearby public buses…). An independent application provider creates an app, Square Spot, which provides a rich view of available resources in a given area, enabling a user experience such as this:

Pierre likes to go out at night in the Champs-Élysées area. Before going out, he likes to know how crowded the area is, and the best way to get to there (using a private car or using public transportation). He uses Square Spot to see how many people are there (if too many, maybe he decides to go to the Latin Quarter) and the availability of parking spaces (either on street or on private parking lots). As not many parking places are available, Pierre decides to go by bus. And later on, when Pierre wants to go back home, he uses Square Spot to decide whether to look for a taxi or wait for a bus.

In the example above, several providers generate real-time data that, in the end, can be utilized by a service developer that creates an app and sells it through an application store. This is a straightforward B2C example, but DDX can be used in B2B scenarios as well.

6.2. Utility scenario

Another example can be picked up from the utility segment. This is a B2B example (in fact a B2B2C). Here, an electricity retailer could benefit from opening the information coming from their customers' smart meters and home energy boxes (with their approval) so that third-parties (with a specific agreement with the electricity retailers) could take that information and combine it offering valuable real-time information (meteorological, generation/consumption forecasts, user location…) providing additional services to the retailer customers. That way, the retailer could reduce churn by providing better services to their customers.

These examples illustrate quite varied scenarios that rely on a role of aggregation and exposition (exchange) of real-time data so that service providers can discover the data that fits their needs and create new applications.

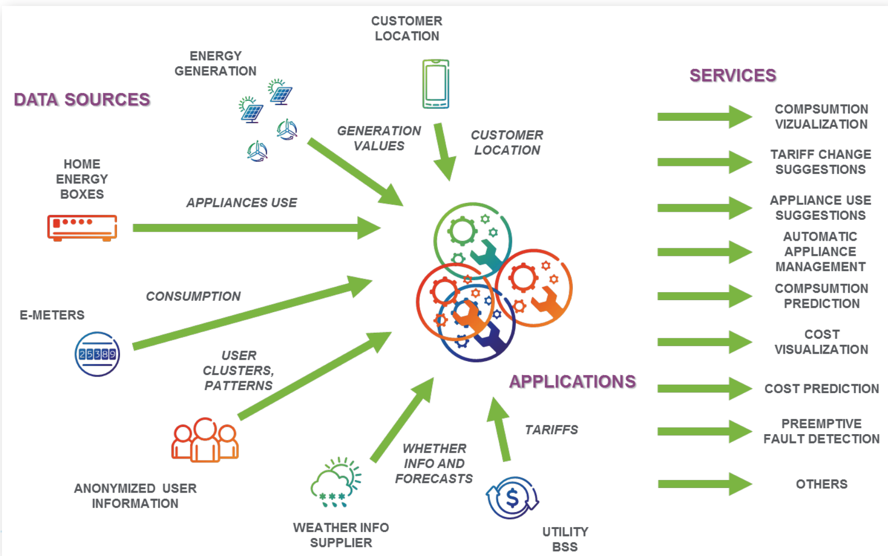


Figure 10. DDX in a utility scenario

6.3. Recapitulation

Depending on the scenario, different possibilities can be considered: an open scenario in which a telecom operator plays the DDX Operator role to their own corporate customers (thus making them play the Data Owner role), in the same way as it provides M2M connectivity for their customers' devices. More locally-oriented scenarios are likewise possible. In the previous examples, a city can sponsor or even directly play the DDX Operator role in order to catalyze the innovation in its area of influence and generate better services for their citizens. In vertical scenarios as the ones described in the utilities segment, these companies could play that role in order to create new services for their own customers.

7- Status

The DDX challenge is mainly in the business plane. Although the technological requirements are demanding, business feasibility is the touchstone of the concept. We have managed different alternatives as a technology supplier, especially when it comes to the segmentation of the offering and the value proposition that should be provided. We have addressed the business feasibility of the DDX concept by running some business development activities within BUTLER in order to determine how profitable the DDX role could be and what kind of players could play such a role. Tier 1 telecom operators were approached in order to validate the business assumptions that were made in order to support the business model. The following conclusions came out:

- Taking into account only IoT data is a reductionist approach. Any kind of data streams (and also static data sets) should be taken into account when considering the setup of data-centric marketplace.
- Although the DDX concept is an attractive new business opportunity, it is difficult to quantify its market size.
- A Pay-as-You-Grow pricing scheme is a MUST towards Data Consumers, including initial free training data sets. However, alternative pricing schemes need to be considered for certain scenarios where PAYG tracking is unfeasible (e.g. fixed price, bidding, bundling etc.)
- Subsequent introduction of Open Data sources would possibly be a must in order to evolve this initial operation model into a full-scale data marketplace.
- Need to further develop the awareness of a Data Brokering business among the Developers Community.
- A business model based only on the distribution of data streams proves to be weak. Service Developers (Data Consumers) MUST be offered additional functionalities. Thus, a basic set of analytics functionality should be included.

We are in the phase of setting up a DDX trial with a Tier 1 telecom operator. It would determine whether the DDX concept is feasible and whether the DDX building blocks will be included within the Ericsson product offering. On the other hand, we are working with different partners in order to find out which analytics tools could be offered to Service Developers.

8- Conclusion

We believe that the DDX framework may become the standard platform for bridging the real-time data communications world with the Application world, and be applied in different scenarios due to its potential as horizontal enabling technology. At the same time we envision that most real-time data ecosystems will originate in high density urban areas (megacities and ICT-intensive smart cities in general).

For those reasons Ericsson is establishing both global and local partnerships with a number of key agents so that the critical mass of actors in a local ecosystem can be secured, and by that, a productive data marketplace for all of them. We welcome partners (device manufacturers, municipalities, public services, utilities, business schools, developers...) who want to engage with us in this vision.

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