SensCity: a new project opening the way for sustainable services in the city based on a mutualised M2M infrastructure

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Abstract

As ICTs became more powerful and accessible it became evident that objects would start to communicate. M2M progressively completed the idea of smart objects and M2M networks came into being, opening new scopes for services. Moving away from application orientated networks; SensCity will build a mutualised M2M infrastructure for sustainable city services. The project is led by a consortium of industrials, SMEs and research laboratories. This paper introduces the scope of services targeted by SensCity and overviews related technical and scientific issues. One concern is how to appreciate environmental impacts and benefits for this particular kind of PSS.

Keywords

Design for environment, impact assessment, M2M, product service system

1 INTRODUCTION

The project Senscity is a collaborative project involving a telecom operator, SMEs and research laboratories and is funded by the French ministry under the cluster of competitiveness label [1]. It seeks to combine the dynamics of small high-tech SMEs along with the forces of academic research and the experience and strength of a telecom operator, in the field of Machine-To-Machine (M2M) communication. The idea is to use a unique M2M infrastructure to construct an original city-wide telecom network that would support a great variety of services for its residents. These services would be structured around local M2M networks linking different types of sensors scattered around the city to a centralised M2M platform.

As environmental consciousness increases, particularly in today's global context of economical crisis, any new project must certainly pose the question of Sustainable Development. All the-more-so in a project dedicated to M2M services in the city. One of the important ambitions of SensCity will therefore be to develop Sustainable Services for Sustainable Cities.

The questions that this will raise are numerous; this article will give an overview of the different challenges as they are conceived from the start of the project. We will trace the evolution from everyday "things" to a project for urban M2M services and take an insight to the possibilities opened out for Product Service Systems (PSS). Some illustrations of M2M urban services will be presented.

2 AN M2M INFRASTRUCTURE AND SUSTAINABLE DEVELOPMENT

2.1 Sustainable Development and ICTs

A Fair Balance

It is becoming more and more evident, and this well before the outbreak of the current financial crisis, that the model of everlasting development at any cost is impossible to maintain. It is important to keep in mind that one of the important goals of the project is the respect of urban sustainability.

In 1987, the Brundtland Report officially laid the basis for sustainable development [2]. Since then, some authors have stressed on the fact that there is a tendency of forgetting that the satisfaction of needs in developed countries must be "combined with the requirements for a nation as a whole to keep its consumption level within an 'ecological scope'" and at the same time, compatible with "the goal of raising the material standards of living in poor countries" [3]. In a paper on urban planning, Campbell explains the triangle showing three priorities and three resulting conflicts (Figure 1). "'Grow' the economy, distribute the growth fairly, and in the process not degrade the ecosystem." [4]

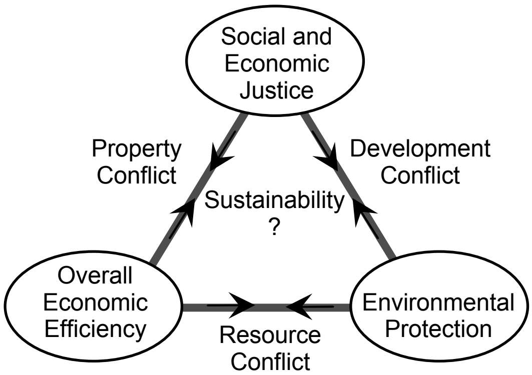

Figure 1: Green, Profitable and Fair.

The term 'grow' must be consistent with the Brundtland recommendations. It is only acceptable if it means a significant reduction of input resources and is principally directed to activities demanding less energy and fewer resources. A fair distribution between generations must also be fair to poorer countries and amongst social groups within a country. Special care must be taken with the ecosystem as decisions taken on a local city scale would affect ecosystems on the other side of the planet. The respect of future generations therefore implies that any development must, in the very least, respect a fair balance between economical, social and societal and environmental benefits under these conditions.

The nature of micro-electronic products involved in this project means that particular attention must be paid to global consequences and to the benefits or drawbacks that would be obtained.

The possible role of ICTs

Since their beginnings, micro-technologies have been making fast progress. Together with developments in other domains, like informatics and ergonomics, they have made possible a spectacular development of Information and Communication Technologies (ICT) as shown in Figure 2.

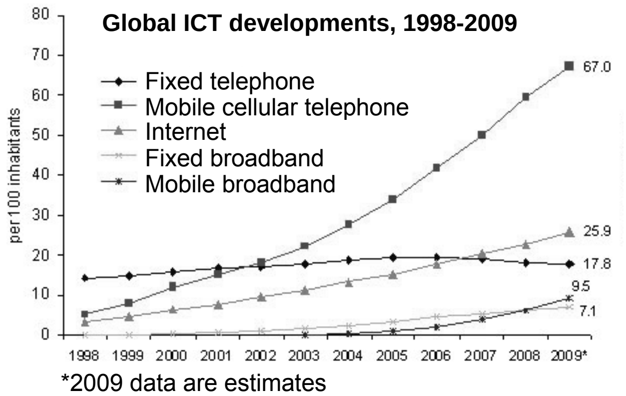

Figure 2: Growth of ICTs [5].

Low-cost potentials for mass production combined with low energy consumption during the use phase of their life cycle, particularly if compared to other heavy mechanical or electrical equipment, raise hopes of low environmental impacts for such electronic devices. These technologies can lead to important changes in our lifestyles and working conditions. They can modify the perception of our environment, homes, industries and towns. The very concept of citizenship must be reviewed with ICTs. They open up possibilities for a multitude of new concepts and new uses. ICTs have often been cited as a chance for sustainable development in so much as care is taken to avoid the rebound effects [6].

2.2 From RFID to networks

Things and smart objects

In a world tuned to internet and the world-wide-web, the "internet of things" is also gradually taking shape and becoming a reality. "Things" people our world. They can be designed either to help us or become too complicated for simple use. The questions of the ergonomics of things have been posed in [7]. As if to overcome the problems of simple use, the idea that things could communicate and therefore become "smart" began to germ. Smart objects are basically objects that communicate. They can communicate with man and also between themselves.

Amongst the different possibilities opened out by smart objects, a few illustrations can help to fix ideas: it is not uncommon to see the garage door open automatically as the owner's car approaches; the alarm goes off as the burglar tears the painting off the wall; point the PDA towards an electrical appliance and the user manual appears on the screen.

Smart Objects seem to concentrate all the burning questions concerning practices in usage. Are they useful? Do they fit into our lifestyles today? Are they harmful? Can we cope with their use? Will they intrude into our privacy? Are they acceptable? ... They have a tendency of destroying the barriers between the professional and private spheres of our lives [8]. There are basically three ways of tackling these problems of use, especially in the quest of new communicating objects: marketers study how to obtain value in existing markets for the future objects; ergonomists make sure that the objects are easy to understand and to manipulate, making the value accessible; sociologists determine if they make sense to the user and in that way, create the value |9].

From the technical point of view, if you consider that smart objects need to be rather mobile, or at least not always close to a telephone line or some other power line capable of providing a communication support, then communication must go wireless. In order to help achieve this, numerous short-range wireless communication protocols focus on the issue.

RFIDs

One particular set of communicating objects that can be identified is RFID. A radio-frequency link needs to be established with mobile objects that want to communicate. Next, each object must be identifiable. The simplest way is to give it an identification number and the RFID becomes an electronic tags. The barcode is actually an ancestor of modern RFIDs.

Actually RFID technologies first appeared during World War to identify planes as being fried or foe. The size of the devices has obviously no common measure with today's possibilities. Today it refers to an electronic device capable of basic communication. Miniaturised it can be stuck, "tagged", on to any ordinary object and make it "communicate".

Passive tags

Le simplest RFID does not have its own source of energy. Such a passive tag is equipped with an antenna that captures an RF signal from a second, more powerful device, known as the reader. The reader must come in close in order to communicate with the RFID tag. The energy contained in the incoming signal can then be used to drive the tag allowing it to re-emit information contained inside (Figure 3).

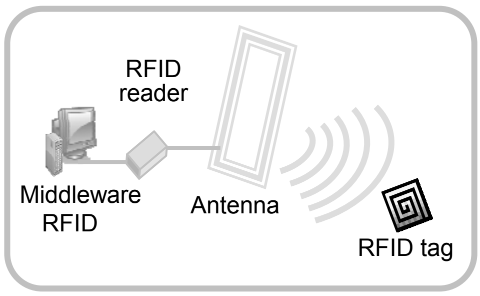

Figure 3: RFID communication.

The minimum of information necessary is an identification number that has to be unique to the object and recognisable by the reader. It could also contain some other simple information but without an internal power supply, possibilities are very limited. RFID passive tags are cheap and widely used for identifying objects such as commercial objects, but are not directly the subject of this paper.

Active tags

Increased functionality becomes possible if the tag possesses its own internal power source. An active tag can communicate over a much larger radius and hundreds of meters are quite possible even in difficult environments, like across buildings or other unfriendly obstacles. Another advantage of having an internal power source is obviously the increased capacity of stocking and processing information.

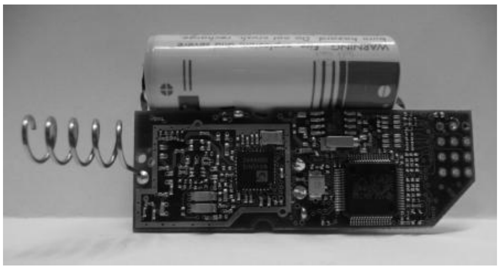

Figure 4: Coronis Active Tag Communication Module.

Active tags (Figure 4) can be associated with all kinds of machines, sensors or actuators. With active tags it becomes possible to consider placing them all over the place, doing all sorts of things. If distances become too long, repeaters can be placed between the tag and its reader.

Capillary Networks

In this way we construct a network. The ordinary RFIDs in the network will execute activities locally, such as collecting data or other functions. They are called end-points. Others, the repeaters, will be used to forward the data towards different points in the network. Of course RFIDs can also combine the repeater function and carry out local activities. Somewhere along the line we may want to interconnect the local network to existing telecommunication networks, like internet or mobile networks. A gateway is necessary to communicate locally with the RFIDs and distantly via these larger more extensive networks.

Our network begins to look like a sort of capillary network able to feed or receive information from the other major networks. Different topologies exist like star; tree and meshed, they are illustrated in Figure 5.

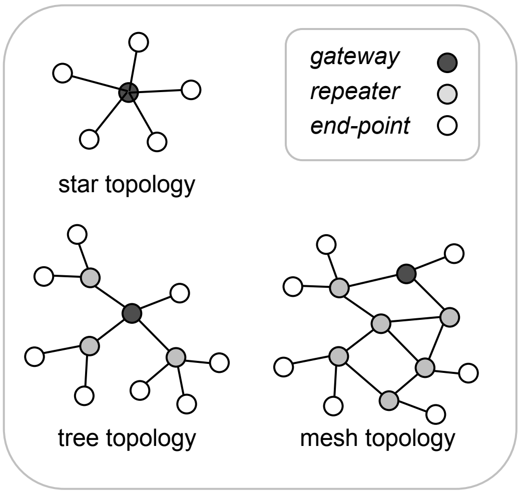

Figure 5: Network Topology.

Of course, all this is without considering technical difficulties related to the absence of universal language and communication standards, neither the problems of acceptability due to the installation of such networks all over the place.

2.3 M2M infrastructure

Exchanging data between objects independently to human intervention is called Machine-to-Machine communication. The earliest uses of M2M were by the American space agency, NASA and some large petrol companies. From the early 2000s, le M2M concept was formalised in various white papers throughout the world [10-11]. The concept results from the association of ICTs and smart objects enabling the objects to interact with information systems without human intervention. M2M can be considered as a technical artefact that extends ubiquitous computing (i.e. human-computer interaction in which information processing is completely integrated) to everyday objects and activities to machines and objects.

M2M infrastructures offer wide possibilities for telemetry applications. However to build up such systems it is important to consider what must go to or come out off a machine. Here, the essential elements are the sensors linked to the machines. They represent the awareness and this is what justifies the need to communicate.

Once again, advances in micro- and more recently nano-systems provide low-cost miniature sensors and actuators of all kinds allowing them to be disseminated all over. Physical values such as temperature, pressure, voltage, acceleration, counters, etc. can be measured and data from the different sensors can be aggregated together enabling decision centres to respond in real-time to evolving contexts. Where actuators are available it can be possible for the system to take action independently. In other cases it is possible to resort to traditional services that are enhanced by the information collected and processed by the system.

Figure 6: A solar powered gateway.

It is estimated that there are potentially hundreds of billions of machines that could be inter-connected in the world. The environmental impact of M2M communications even at much smaller scales would become a major issue. Furthermore, machines obviously are very different and display heterogeneous natures. Very much coherence and convergence will be necessary in order to make them link to one another. Today there appears an urgent need for international norms and standards.

Vertical Applications

M2M systems find applications in many different areas: transport and logistic; home automation and security; energy management; healthcare; utility metering; public infrastructures and environment, to sight just a few of them.

Generally speaking however, most systems used today are proprietary systems and treat only a limited number of applications, basically just one. The market is orientated vertically and systems are expected to run in parallel in competition with one another. This situation evidently cannot carry on indefinitely. For economic, technical and environmental reasons the systems must evolve towards open infrastructures.

An Urban M2M Network

A good way of moving away from vertical-orientated applications towards non-proprietary open systems is to delimit coherent geographical domains displaying a clear interest in multiservice. Such perimeters could be, for instance, premises of homes, industrial zones or international transportation networks. Amongst them is the city. SensCity occupies this particular area of study, full of promising applications.

2.4 PSS and M2M services

If the prospect for developing interesting services in the city is clear it must also be clear that the choice and more importantly, the model for services, are very important considerations. The case of PSS is therefore interesting to examine and can guide the choices made.

An Industrial Product-Service System (IPSS) is “an integrated product and service offering that delivers value in use”. Various authors have described PSS and show the potential interest for sustainable development [12-13]. PSS strives to shift perspectives from focusing only on products to a more systemic approach opening the way for radical innovation. The products are owned by the producer throughout the complete life-cycle and this will change his vision and encourage interaction with final users and the rest of society. The product is considered as the carrier while services, as experienced by the end-user, appear to be dematerialized. Access to such services using ITC is also very promising and can permit customised services which are thought to be generally more sustainable. The PSS structure, through better maintenance and adequate upgrading ensured by professionals over the full life-cycle of the product, brings the promise of services with longer life and better quality. This would contribute to more sustainable services providing that care is taken to limit abuse, for instance due to too easy access to the services.

2.5 Requirements for the Infrastructure

A well planned M2M infrastructure could become a particular advantage for cities. On one hand we see opportunities for new services through a new mutualised communication infrastructure and on the other there is a growing and urgent need for sustainable development in sustainable cities. It is clear that in order to develop the network on a city scale a certain number of points must be taken into account of during the project.

Environmental

The project must develop sustainable services in a sustainable city that are green, profitable and fair; minimise the environmental impact during the full life-cycle of the services; take into account that the large number of small electronic devices could eventually display large impacts; reduce energy consumption; economise land-use and provide necessary green areas while still allowing the conservation and development of continuous agricultural and natural land outside the city; reduce pollution and noise; promote closed local flows to reduce waste; and avoid ICT rebound effects.

Network

Without going further into detail, the major technical questions are concerned with adopting a universal language of communication between the multitudes of heterogeneous machines; developing international norms and standard communication protocols; the infrastructure must be open with non-propriety systems; sensors and communication modules must be developed together with adequate energy sources.

Services

The domain has to be well identified and service infusion should inspire from PSS. Services should look towards multiservice instead of vertical applications; interactions and solidarity amongst users; customised services; web services; enhancement through sensor network data. They should display good ergonomics; propose good significations of use; be acceptable; have market value and be economically viable.

3 SENSCITY

3.1 Objectives

The project’s goal is to contribute to sustainable development, particularly through environmental considerations, together with the development of an urban M2M infrastructure, comprising the sensor networks and the services associated. These are the motors that had initiated the project SensCity [1]. Is it possible to conceive an embryonic city-wide network with potentially tens or even hundreds of thousands of interconnected sensors and other machines without degrading the environment? Can the nature of the services provided both contribute to relieve the strain of dense city-life and reduce the burden on the environment? These are the important questions that must be addressed.

3.2 Organisation of a “SensCity City”

The “SensCity City” can be viewed at different levels depending on the part of the infrastructure considered (Figure 7).

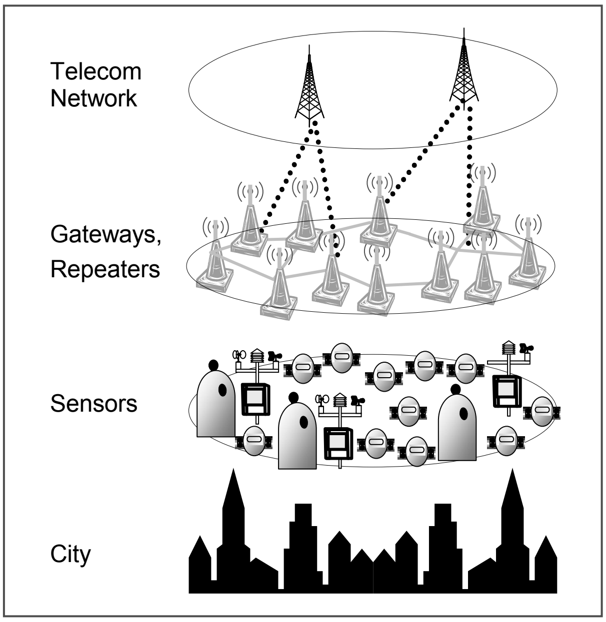

Figure 7: Networks in the City.

The first physical level will be the town structure with its people, buildings and other facilities. The town leads its own life. Next there is a vast network of sensors and actuators in the city. New material can be installed or obsolete ones taken away. The activity of these sensors and actuators can be very high, and once again, have their own life. Above, a set of repeaters covers the town and is ready to relay data and interrogate the different sensors. Yet above, are the gateways that convey data to and fro the lower levels. The gateways are linked via GSM to traditional telecommunication networks. Data will then go on to an M2M platform.

3.3 Proposed System Architecture

The simplified overall architecture of the system is illustrated in Figure 8. The data is collected on the left hand side of the schema. The sensors (or actuators) are distributed in the city according to initial service-requirements. They are associated with their communication modules that are able to connect via the repeaters to the gateways. The data that they gather enters the telecommunication networks through the mobile GSM network and on to the internet. The M2M platform, connected to internet, controls data-collection and sensor-management. For instance, instructions can be relayed to

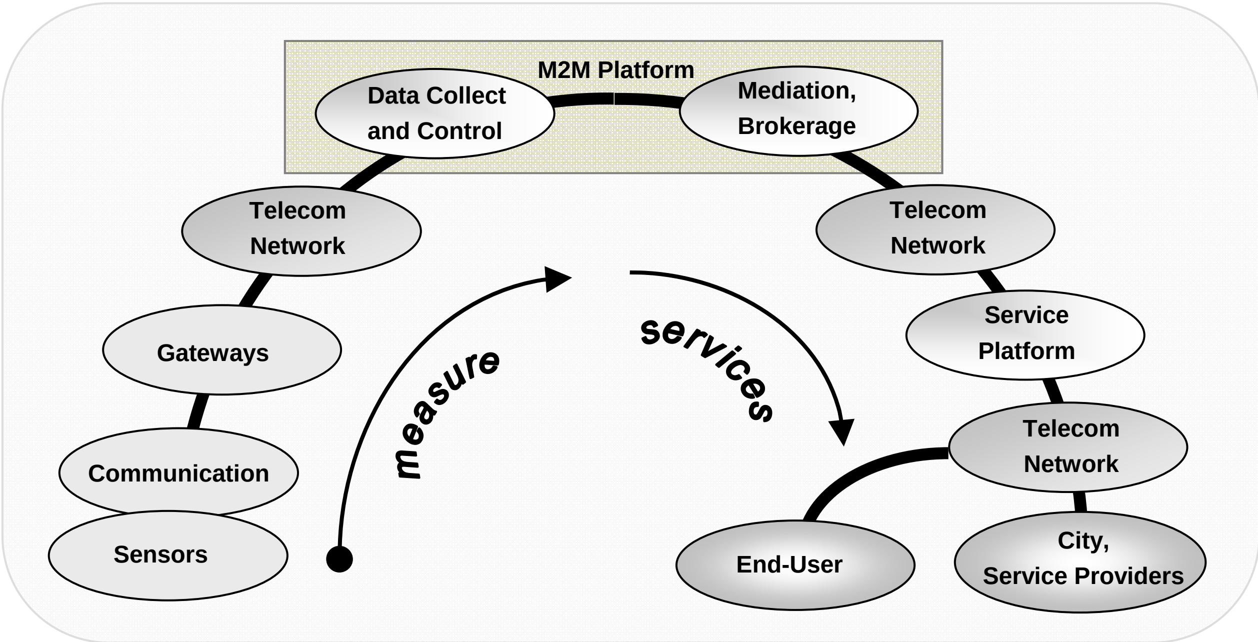

Figure 8: Simplified Architecture for SensCity.

the sensors or actuators in order to modify measurement frequency and times. In the other direction, any new installation of end-equipment can be discovered and integrated into the network.

Services are then be deployed on the right hand. The M2M platform organises data-management and safeguard. It also takes care of legal questions like rights of access to information, ensuring security and privacy. Service provider platforms are connected to the M2M platform through internet and will thus be able to pilot different offers of services, including web services and other types of services. In this way the information is made available for city public administrations or residents.

3.4 Scientific questions addressed in the project

SensCity addresses the global M2M infrastructure. On the technical side the project must develop:

- the sensors and gateways;
- the capillary network and communication protocols, in accordance with application requirements;
- the M2M platform with the functions of mediation and brokerage along with planning and administrative tools;
- the M2M applications together with the framework for new services and standard user interfaces;
- normalisation and standardisation.

As for environmental considerations, the project will pay a particular attention to ecodesign and the appreciation of impacts:

- Life-Cycle Analysis (LCA) methodology adapted to this kind of services will be developed;
- the choice of indicators adapted to the city context is fundamental.

A close cooperation with the SMEs involved with the infrastructure or with services is necessary and the project aims to help them move towards a greater consciousness in ecodesign.

3.5 Project Organisation

The industrial partners of SensCity include SMEs participating at different levels.

Some SMEs install sensors or actuators; others are more concerned with services that make use of the data coming from the different sensors. Yet others are involved in middleware or network management. Of course one SME can also intervene at different levels.

The main interlocutor for the city would be the telecom operator. It is the leader who must globally organise the implementation of the system and insure service continuity, security and quality.

SensCity is an open structure that has high perspectives for evolution. In the future, when the infrastructure is fully running, new actors could integrate the structure at all times so long as they comply with the norms of SensCity. For instance, a new service could be proposed combining data from different kinds of sensors run by different SMEs or new sensors could be introduced.

Planning and Resources

The total budget allocated by the project is 6M€ with a total of 51 man-years. Le project will last from September 2009 to August 2011, although PHDs involved in the project will carry on for an extra year.

2009 will be used to validate the different technologies and define functional specifications of interfaces, equipments and services. 2010 will see implementation of the different equipments and the development of the urban service applications. Finally in 2011 the services will be experimented globally.

Project Partners

The industrial partners of SensCity include Alcion; Azimut; BH Technologies; MIND; Coronis; Dot Vision; E-Gee; HP; Numtech; Orange Labs (project leader) and Webdyn. The academic partners are from the University of Grenoble.

3.6 Illustrations

Various vertical applications of urban M2M services have already been experimented and some are currently working in cities (figures 9-10). The project will pay a particular attention to them in the early stages and will use them as case studies to validate methodological and technological developments.

Glass Recycling Banks

Used glass is collected in glass banks. As the disposal containers fill up they are emptied into a collect truck. The truck has to go round systematically to every bottle bank even if there is not enough glass to be emptied. It is obvious that if the driver knew before hand the filling level for each container it would save a lot of kilometres and reduce traffic and noise.

Figure 9: Glass Collection.

An ultrasound sensor placed in the column at the top can measure the remaining space in the container and send the information to the collector via an M2M network providing a precious service to the city [14].

This service could also contribute to more efficient collects, especially seeing that overflowing containers are difficult to clean and usually mean more complaints to the city council.

Public Lighting

Streetlights and other public lighting are very critical for a city. Their electrical consumption is very high and there are many potential environmental gains for smart-lighting M2M services.

Services using sensors in an M2M network could monitor the state of individual lamps allowing automatic detection of aging or lamp failure. At the same time they could control power and save energy though dimming at certain hours, when street frequentation goes down.

Figure 10: Gateway Installation.

Today, lamps must be systematically changed at the end of their guarantee period because of maintenance. Sensors that can anticipate lamp failure through the detection of unusual functioning could introduce radical change in the way street-lighting is managed and eventually lead to important extensions of the effective lifespan of lamps.

Pollution, noise and weather conditions

The knowledge of pollution, noise and weather conditions with sensors placed in critical points in the city has evident advantages for a sustainable city. Data on pollution is important for security reasons and could de used in real-time traffic control. Information on weather conditions would help understand temperature and wind variation across the city and would be very complementary to pollution level measures. Doctors could combine data on pollution and weather so to advise patients with asthma for instance to avoid certain places.

Here we are obviously dealing with new kinds of inexistent services. Introduction of new service will directly increase environmental impacts in the city. Care must be taken to insure that the services rendered compensate effectively this factor.

Electric car recharge stations

A more futurist application concerns fleet management in the city and in particular problems of energy sources and parking spaces. Potentially, electric cars will become a low-pollution means of transport in cities. There will be a growing need for environmentally friendly installations to recharge car-batteries in the city. The management of a fleet of electric vehicles and a park of recharge stations would be facilitated by M2M services. The recharge stations could use local sources of renewable energy, like solar or wind energy. In this case the M2M network would monitor the park and update information of the state of each station. By combining information from the different vehicles and the recharge stations, they could optimise resources by directing vehicles towards certain stations and help determining, for instance, which vehicles need to be recharged in priority and for how long. Sometimes the vehicles could exchange their batteries for recharged ones.

The same kind of service platform could also serve car-sharing schemes and monitor parking spaces.

4 DISCUSSIONS

4.1 What Sustainability?

The type of services provided by SensCity and the modalities of implementation and exploitation are important issues.

There are different ways to view sustainability in city services. They should, as mentioned above, respect the constraints for a really sustainable city, contribute to the rights of future generations to access le same quality of life and to those of developing countries that aspire better living standards. This could only be true if the services:

- contribute, by their functions, to sustainable cities,
- obey themselves sustainability criteria.

The services proposed by SensCity would sometimes replace existing services or improve them. They could be innovative, resulting from evolutions in society or technological advances. They could also come out of particular features or certain combinations that appear within the network itself.

4.2 Services for a Sustainable City

The services retained should favour the evolution of existing cities towards sustainable ones. As explained above, sustainable urban development in developed countries must not be based solely on means-ends rationality but should examine the environmental consequences of different solutions and be directed towards long-term goals.

Environmental and social considerations

As a first approach we could aim for public services that tend to reduce the inconveniencies and improve the attractiveness of high-density cities that appear more favourable to sustainability:

- Reduce energy consumption to a level compatible with global criteria
- Reduce the use of environmentally harmful materials
- Valorise public transport and diminish pollution, noise and traffic

- Minimise land-use leaving space for continuous natural areas, eco-systems and agricultural areas
- Encourage solidarity, autonomy, independence, integration and exchanges between residents
- Replace open-end flows producing waste with closed-loops using local resources.

Vertical Applications vs. Multiservice

The choice of multiservice as opposed to vertical applications appears to be a positive factor for sustainability. However care must be taken that the infrastructure does not become an excuse for introducing services for pretexts not really complying with criteria of sustainability.

4.3 Sustainable Services for an M2M infrastructure

LCA for Sustainable Services

Any activity has an effect on the environment. SensCity services themselves must be eco-designed, irrespective of the benefits they can bring to the city's context. It is important to compare environmental impacts of different possible architectures, materials, usage and end-of-life scenarios, etc. Impacts are usually measured by indicators using LCA. Indeed it is important to study the services taking account of their full life cycle, that is to say, all the phases from the production of raw materials to transport, fabrication, use and end of life.

In the case of products, methods for LCA are quite well mastered today. For services, methodology is not that straightforward and requires special attention. In our case the mutualised M2M infrastructure and telecom networks must be accounted for. The services, that do not yet exist, must be compared with solutions that are not necessarily exactly equivalent.

Impact transfers must be avoided. For instance, gains in the greenhouse effect could mean adopting solutions presenting undesired water problems. It is important to use multi-criteria to appreciate the effects of running the services. As mentioned before, the system chosen in this project is based on high-tech electronic devices. Some of the services provided would reduce transport needs. In these cases, compared to the transport systems, electronics show relatively poor performances concerning raw material depletion, water pollution and waste generation. On the other hand advantages would be expected in terms of the greenhouse effect, ozone and air quality. All these factors must be considered globally.

4.4 PSS for M2M

SensCity is a good terrain for PSS. The multitude of SMEs concerned; infrastructure mutualisation; mixed technologies; multi-service potentials and necessary interactions with urban actors are just some of the factors that oblige a certain dynamic during the project and would certainly transform the visions of the different partners. The existence of a strong telecom operator as leader can also be a positive factor for conversion towards PSS.

It is easy to understand the rapprochement between SensCity's M2M services and PSS. In the two cases there is a concern for environmental issues.

By their nature, M2M services can be dissociated from the physical infrastructure that makes them possible. In fact that is one of the reasons for mutualisation. A sensor initially set up for a certain application and run by a certain company, can later find use within another service. There is not necessarily a connection between the service provider and the sensor network provider. The provider can even combine data from sensors run by different companies.

Service infusion is high in the two cases. More than not, access to M2M services will be done through some kind of web service. This opens the way for personalised services via the internet, which is another strong point for PSS.

4.5 Economic viability

Of course it is important that the M2M infrastructure be economically viable and interesting. That is why great importance must be given to the research and development of worthwhile sustainable services. Perhaps the real challenge for the project lies here.

5 SUMMARY

The paper traces how the idea of an urban infrastructure for M2M services took form and inspired the project SensCity. The different environmental and other challenges to be faced have been discussed. Illustrations of services provide a good overview of the context and challenges. The issue of PSS has also been treated and the basis has been laid for new services.

6 ACKNOWLEDGMENTS

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