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USING SENSOR-BASED NETWORKS TO ADDRESS GLOBAL ISSUES: POLICY OPPORTUNITIES AND CHALLENGES

This document includes a summary of the discussion from the OECD Experts Conference "Using Sensor-based Networks to Address Global Issues: Policy Opportunities and Challenges", hosted by ANACOM on 8-9 June 2009 in Lisbon, Portugal.

It is submitted to WPISP delegates for information at their meeting on 12-13 October 2009 under Item 9 of the draft Agenda.

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Summary of the OECD Experts Conference
hosted by ANACOM on 8-9 June 2009 in Lisbon, Portugal

1. The OECD held an Experts Conference on "Using Sensor-Based Networks to Address Global Issues: Policy Opportunities and Challenges" on 8-9 June 2009, in Lisbon, Portugal. The one and a half day event was hosted by ANACOM, the Portuguese National Authority for Telecommunications. Sixty experts from government, industry, academia and civil society organisations across OECD member countries were invited to participate in the Conference.

2. The Conference followed up on the 2008 Seoul Ministerial Meeting on the Future of the Internet Economy where Ministers invited the OECD to "analyse the economic, social and cultural impacts of emerging Internet technologies, applications and services, including sensor-based networks" (Seoul Declaration[1]). It built on OECD work on Radio-Frequency Identification (RFID[2]) and on the High Level OECD Conference on "ICTs, the Environment and Climate Change" (Helsingør, Denmark, 27-28 May 2009[3]).

3. The Conference focused on "Sensor-based networks" or "sensor networks" which are groups of sensors with a communications infrastructure intended to cooperatively monitor and record health or environmental conditions at diverse locations and perform other networked operations.

> Sensors are fixed or mobile processing devices that measure or detect a real-world condition, such as motion, heat, light or location and convert the condition into an analogue or digital representation.

4. The goal of the Conference was to foster discussions among experts in different fields (health, environment and transportation) with a view to helping policy makers:

- Understand Sensor-Based Networks and their potential contribution to economic and social welfare.
- Identify how to further stimulate innovation in this area and foster the development of these technologies where they are most needed and are the most promising.

5. Discussions on the first day concentrated on illustrative examples of sensor networks applications in three areas: **health and elderly care** (session 1), **protection of the environment** (session 2) and **transportation** (session 3). The second day focused on policy discussions (session 4) to approach the subject matter in a horizontal manner and to identify key issues common or specific to each theme. The

1 . See www.oecd.org/dataoecd/49/28/40839436.pdf

2 . OECD Policy Guidance on RFID, www.oecd.org/dataoecd/19/42/40892347.pdf

3 . www.oecd.org/sti/ict/green-ict

concluding session brought together some of the main themes arising during the workshop, with a view to highlighting the key policy issues to be addressed in the future and possible next steps for the OECD.

6. This document, prepared by the OECD Secretariat, summarises the discussion in the four sessions and includes the Chair's main points. Presentations delivered at the Conference and other materials are available at: www.oecd.org/sti/ict/sensors. The list of speakers with their affiliation is provided in annex I.

Opening session: Welcome and keynote speeches

7. The Conference Chair, **Luis T. Magalhães**, welcomed participants to Lisbon, thanked ANACOM for hosting the conference and the OECD secretariat for preparing this meeting. He presented the OECD and the Committee for Information, Computer and Communications (ICCP) on which he serves as Vice Chair.

8. Member of the board of ANACOM, **Teresa Maury**, welcomed all the participants and introduced the theme of the conference and the main issues to be addressed. She noted that, at a time of economic crisis which leads us to rethink many of our previous choices, this Conference provides an opportunity to discuss the potential for sensor networks to help address global issues, to identify their benefits and the drivers for their adoption, as well as the issues they might raise. Governments will have to answer many complex questions. Solutions may vary depending on the sector or application. However, in an ever-changing environment, expertise and advice is always welcome to help policy makers develop appropriate frameworks and responses.

9. On behalf of the OECD, **Anne Carblanc** thanked ANACOM and Portugal for their active involvement in the area of ICTs and their generous hospitality. She highlighted the rationale for organising the Conference: *i)* the Ministerial mandate of 2007 which invites the OECD to develop, by 2010, an OECD wide Innovation Strategy, *ii)* the Seoul ministerial mandate from June 2008, and *iii)* work carried out on RFID over the past three years by the OECD which includes policy guidance to enhance business and consumer benefits from the use of RFID while proactively taking into account information security and privacy. She explained that the aim of the discussion was to answer two main questions: *i)* whether and how the economy/society could benefit from sensor networks and *ii)* how policy makers could help foster sensor networks where they are the most needed. Finally, she stressed that while three sectors had been selected to illustrate the discussion, it did not imply that they were the only ones where sensors were deployed or had a potential for further deployment.

10. **Florent Frederix,** head of RFID sector in the European Commission (EC), introduced the EC Roadmap for RFID, started in 2005, and the Roadmap for the Internet of Things, started in 2008 and planned to end in 2011. The recent adoption of the EC Recommendation on RFID in May 2009 is expected to be followed by a Communication on the Internet of Things. A number of large scale RFID pilot projects will be funded via the Information Communication Technology (ICT) policy support programme in the next few years. The Future Internet Initiative will integrate policies with regards to the Internet of Things. Even if a majority does not see the Internet of Things become a reality in the near future, sensor networks collect more and more personal data every day. He pointed out that RFID was an old technology that appeared on the policy agenda recently and that the EC's experience on RFID policy making shows that taking appropriate measures prior to the full development and deployment of the technology avoids unnecessary costs and reduces acceptation issues. Therefore, one main issue the EC has to address is the establishment of a workable framework for Privacy Impact Assessments for RFID and Internet of Things.

11. The head of Telenor Research and Innovation, **Hans-Christian Haugli,** presented some projects implementing sensor-networks to optimise logistics such as: combined use of RFID and temperature sensor

loggers to track salad temperature and decrease the 30% waste mainly caused by transportation from manufacture to the store; waste management optimisation by tracking the filling level of waste containers and reporting this information in real time; livestock quality improvement by tracking roaming sheep to detect mortality patterns and better controll the animals' environment quality. He pointed that sensor networks applications are fairly unknown territory at this stage. Telenor is exploring vertical value chains (*e.g.* salmon farming, electricity metering, etc.) to build up expertise in view of a market that is expected to shift towards more horizontal layered value chains where sensor data will be shared across different software applications. Future network effects when billions of sensors can provide data to any third party application in a safe and cost effective way is beyond comprehension. Mr. Haugli concluded by reminding of key issues to be resolved, such as business models, standard interface and data traffic models, security, and privacy as well as government involvement.

12. **Prof. Kitsuregawa**, from the University of Tokyo, presented the Information Grand Voyage Project and introduced applications such as My Life Assist and Digital Helper. These applications combine data extracted from users' Internet habits and offline behaviour (*e.g.* location, RFID tracking, purchase history, health information). Their goal is to provide advertisement based on derived potential desires and to provide suggestions such as hints on how to increase health status by changing certain habits (*e.g.* use the stairs instead of the elevator).The project includes efforts towards anonymisation of data collected for data mining purposes. Pilots demonstrated high levels of acceptability and attractiveness for such applications.

13. **Dominique Guellec**, from the OECD Economic Analysis and Statistics Division, explained how this Experts Conference on sensor-networks was related to the OECD innovation strategy, a horizontal project that aims to better understand how innovation works in the global economy and will result in a broad-based series of policy recommendations. The nature of innovation is wide, encompassing technological innovation as well as new ways of using existing technologies and of leveraging their effects. In that respect, sensor-based networks offer a case in point: it is not only a matter of technology development, although this is of course necessary; it is as importantly an issue of improving the conditions of use of the technology: funding new uses to provide new services to customers and businesses, or to improve the conditions in which existing services are provided. Many examples of sensor-based technologies and applications relating to health, to transport or to the protection of the environment that will be presented during the Conference should also be discussed in light of their potential to increase innovation and its positive impact on society, the environment and the economy.

14. The discussion that followed the opening session highlighted the potential of sensor-based technologies and networks to be used in many different contexts. The issue of privacy protection and of compliance with varying data protection rules was raised by several participants. Governance issues were also mentioned with reference to the Internet of Things.

Session 1: Health and elderly care

15. The moderator, **Elettra Ronchi**, from the Health Policy Division of the OECD Secretariat, introduced the session aimed to provide an overview of different uses of sensor networks to enable home treatment and monitoring of patients.

16. **Mike Eklund**, from the University of Ontario Institute of Technology, Canada, highlighted the challenges posed by the global issue of ageing population and how sensor-based networks could help address it. An increasing number of people need medical attention, but systematic hospitalisation impacts living standards and increases cost (whether for the social welfare system or for families). Current efforts to alleviate these impacts are mostly concentrated on Electronic Health Records or Telemedicine and home care. Telemedecine could eventually save an enormous amount of money if efficiently deployed and

operated and, possibly including smart monitoring systems and sensors. Sensors could help to autonomously detect and alert patients and, if needed, care providers of any accident, acute illness or deterioration of condition. Such assistance could allow patients to remain at home in a safe and secure environment and delay their transition to group care facilities. Examples of technologies include Bosch's Health Hero, IMEC wireless ECG patch or Merlin@hometransmitter's wireless technology. Mr. Eklund concluded by underlining concerns over the protection of health information privacy. He stressed that privacy and security must be critical components of any sensor network home care system, although experience seems to show that many users are willing to accept some loss of privacy in exchange for increased health security.

17. **Deborah Estrin,** Director of the UCLA Center for Embedded Networked Sensing (CENS), explained that mobile sensing has started to be looked at as a very important and affordable way of applying sensing technology. By using a combination of sensors embedded in mobile phones, sensing streams can be leveraged. For example, AndWellness, using Android phones, tries to see user's patterns and trends over time to improve their health by gathering behavioural information through simple questions regularly prompted to the users and by collecting automatically data from mobile phones sensors. Behavioural histories can be accessed on the Web and visualised on a map. Patients can then improve their habits according to their location. Another example is "Ambulation" which monitors chronic disease progression and responses. It works with a GPS and accelerometer to capture activities and classifies them (walking, driving, wheelchair, etc.), allowing trends detection (indication of fatigue, changes in living habits, etc.) and identification of solutions. Again, data comes from prompted and measured inputs and enables a better feedback loop for health care professionals. Beyond health records, such systems create a full record of one's everyday life, raising important privacy issues. The concept of Personal Data Vault where all data is the user's property is being considered. In conclusion, Ms. Estrin noted that this technology is applicable in many sectors (*e.g.* protection of the environment, transportation and sustainable living) and therefore has a promising economic potential.

Contributions by the Panel:

18. The concept of Personal Health Systems (PHS) was introduced by **Jose Luis Santos**, Associate Professor at the University of Porto. PHS involves sensors, sensor networks, signal processing, powering, wireless communications and information systems. PHS is a complex area of research as it relies on various technologies with different levels of maturity, sensors being less advanced than communications and information systems, and biochemical sensors being more complex than physical sensors. The development of PHS also requires a multidisciplinary approach which is often challenging. Most of the developments in this area are based on microelectronics (MEMS) components that could be replaced in the future by nanotechnologies. Optical fibre in PHS is simultaneously a sensor and a communication channel. Combining optical fibre sensing with wireless out-body communication seems to be an ideal combination but is only beginning to be developed.

19. The head of Photonics Division of the Institute of Photonics and Electronics, in Prague, Czech Republic, **Mr. Jiri Homola**, explained that most physical sensor technologies will continue to evolve but are already mature, but that chemical sensor and biosensor technologies are still at a developing stage facing several technical challenges. Biosensor technologies are more complex than physical sensors and require collaboration of experts from various areas (physicists, chemists, molecular biologists, processing engineers, etc.). Biosensors present a promising technology which will enable detection and identification of a large variety of molecules (e.g. biomarkers, antibodies, hormones) resulting in better and more detailed diagnostics. Biosensors will make it possible to perform diagnostics and treatment monitoring remotely without the need for the patient to visit a medical facility. Health care providers will receive biological data in real time and, if needed, contact the patient to provide instructions about what he/she

should do. Centralised diagnostics will be critical and methods to process such data efficiently are not available so far.

20. **Keith Errey,** CEO of Toumaz Technology Limited explained that if network technologies have been widely developed, "the last metre" still raises issues. The technology to transfer the data over that last metre must be simple, automatic, safe, unobtrusive, continuous, affordable and use low power. Current technologies are not adapted, either too power hungry or using the worst frequencies (*e.g.* bluethooth). Toumaz's latest technology (Sensium/Digital Plaster) meets the requirements for body-worn sensors and intelligent wireless infrastructure to cover that last metre. In order to avoid being overwhelmed by data, it transmits key data only when necessary and therefore concentrates on the important information.

21. The project Netcarity was introduced by its Technical Co-ordinator, **Rebecca Simpson.** Netcarity is one of four large-scale European projects representing a total budget of EUR 2 million, and expected to reach EUR 1 billion in the next five years. The goal is to research and test technologies which will help older people to improve their quality of life, independence, safety and health at home considering in particular issues such as security, connectivity and wellbeing ("Ageing successfully and in place"). Demand in this area is large as over 30% of people wish to age at home with professional help. In order to implement such a large project, Netcarity uses a range of devices (automatic lightning, smoke and fire detectors, electronic door locks, etc.) and communication tools (video phone, tablet interface, centralised control system, etc.). Sensor systems' current implementation, tested on 100 households, shows that the main problem about privacy is not technical as security can be engineered, but rather related to who has access to data and how to get users' acceptance.

22. **Mr. Dooho Choi**, Senior Researcher at the Korean Electronics and Telecommunications Research Institute, pointed out three security key management issues remaining to be solved when using sensor network technology in health care: *i)* data confidentiality and integrity. Information linked to health is highly identifiable and personal and needs to be protected. Some current technologies include symmetric cryptography; *ii)* Smart access control. Many different actors are involved in life vital applications (patients, doctors, nurses, families, emergency staffs, etc.) and access to patient data should be allowed only when needed (*e.g.* emergency situations). Some experimental research exist; *iii)* Location data protection. Information on the location of a person carrying a sensor device should not be disclosed.

Discussion[4]

23. The discussion highlighted the following points:

24. *More interdisciplinary research needed*: sensors networks begin to be developed for medical purposes and will enable better diagnosis, however, more research is needed. It is important to bring together researchers from various areas to make progress. Layers of interdisciplinary expertise need to be integrated in the projects as they evolve (mix of hardware, maths, clinical, physiological modelling, etc.).

25. *Technology almost mature:* overall, technology is not an obstacle for the deployment of sensor networks in the health sector and many of the applications previously introduced could already be built with existing technologies and architectures. Some chemical sensors are mature (*e.g.* glucose for diabetic) and others will make progress in the next 5 to 10 years. However the "last meter" between network and sensors attached to the human body might still be challenging.

4. The summary of the discussions reflect the various opinions expressed. It should not be read as reflecting a consensus among participants.

26. *Privacy and security to be integrated at design stage*: using data gathered through sensor networks requires users' acceptance and data protection is a very sensitive subject when it concerns health issues and involves also non-health related information such as location data. The extent to which individuals would accept weaker privacy protection in exchange for better health services and increased quality of life is still unclear. It is difficult to quantify the cost implied by medical privacy measures, and with respect to privacy regulation, the lack of consistency across borders is an issue. To protect confidentiality, security controls or cryptographic components such as access controls should be included in health sensor networks applications as many actors are involved in life-vital applications. While it would probably be more cost effective to address security and privacy from the outset of projects, these dimensions are often considered later in the project development.

27. *Standards to be developed*: The telecare market is expanding and it is becoming important to start thinking of standardisation. Those new applications are long-term cost efficient and major investments are likely to come from health care providers. Hospital markets are clearer than other health markets.

28. *Role of government*: Governments have a key role to play with respect to the adjustment of health care legislation to these technologies and to fund R&D projects. Governments also have an educating role to prepare citizens and health care providers for the transition towards these new ways of approaching health care.

Session 2: Protection of the environment

29. The moderator, **Graham Vickery,** from the OECD Secretariat for the Working Party on the Information Economy, introduced the session aimed to focus on the development, impacts and outcomes of sensor networks that can be used to improve environmental performance.

30. **Darrell Williamson,** Deputy Director at the ICT Center of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia, explained that sensor network pilots related to the environment implemented by CSIRO result from national environmental policies rather than commercial approaches. The majority deals with water treatment and measurement of ocean conditions as well as agricultural sustainability. Projects aim to provide a data-driven approach to scientific discovery through the development of sensor network technologies that will help transform our understanding and management of the environment and natural resources. This implies being able to gather data about natural environments as well as built environments at a spatial scale and at an intensity level not easy to achieve by other means (manual collection, data logging, remote sensing). However, it is difficult to deploy large, long-lifetime systems due to scalability issues and high cost of sensor devices, deployment, maintenance, etc. There is room for improvement in energy/information cost tradeoffs. For most of those projects, privacy issues are not relevant but confidentiality issues might play a role in commercial contexts.

31. **Karsten Schischke** from the Department of Environmental Engineering of the German Fraunhofer Institute for Reliability and Micro-integration (IZM) presented a project on precision farming based on sensor networks. Following a request from the German government, the Institute – working on the miniaturization of sensor nodes already for a couple of years, where the size of a grain is almost achieved – investigated the innovation potential for sensor networks and their broad implications with a view to reducing significantly the amount of water used in farming. In their scenario, large quantities (several thousands) of sensors are distributed across a field to determine humidity and provide water exactly as needed in each part of the field. Mr. Schischke indicated that the components would not be costly if produced on a large scale but that the technology of underground sensors with communication is difficult to achieve. Furthermore, the users being farmers generally not versed into IT, the technology had to be user-friendly. Nevertheless, he stressed that a conservative analysis concluded that such applications

could save a minimum of 1 to 2% of water representing 1 to over 3 billion m3 per year, and that water saving legislation could provide a good incentive for adoption.

32. **Beth Wozniak**, president of Honeywell Sensing and Control, presented her company's solutions to help reduce energy consumption and increase the efficiency of machinery and industrial processes. She explained that they had installed over 50 million wireless sensors in applications in industries, buildings, homes and structures; automation and control solutions being their largest sensor market. Standardisation is important as customers have made significant investments and products have to operate seamlessly in their environments. Wireless sensor networks provide ability to monitor and control assets that could otherwise not be monitored. Ms. Wozniak pointed out economic benefits such as increased productivity, reduced energy usage, improved maintenance effectiveness and increased safety. Costs savings are the main driver for adoption and vary according to sectors. In buildings, for example, wireless sensors eliminate the cost of deploying wires and only a relatively limited number of sensors are needed. The emerging market for industrial wireless sensor networks is expected to be USD 5 billion in five years. Challenges remain with battery life and compatibility with legacy systems. Government support for research and appropriate regulation such as on energy efficiency, emissions reduction could play a key role for adoption.

Contributions by the Panel:

33. **Joao Barros**, from the Carnegie Mellon Portugal Program, noted that research to understand how to get data processing, communication and control to work together was still necessary. Customers would like to have ready solutions straight off the shelves that can be deployed easily; however, any successful system has to be carefully adapted to the environment and to already installed applications. Standardisation could be an answer but the multiplicity of applications might make it difficult. Mr. Barros then described two projects: *i)* vehicular networks as enablers for sensing environments, where vehicles equipped with wireless sensors provide data on their surrounding environment, and *ii)* forest fires prevention, a project that is not deployed due to the number of sensors that would be needed. Interdisciplinary research is essential, solutions will be found by experts with various backgrounds and different knowledge.

34. **Lucio Sobeilman**, from the Department of Civil and Environmental Engineering, Carnegie Mellon University, pointed out that multidisciplinary research requires a common language among experts. He highlighted that efficient data management is needed in a number of cases, for example, where all bridges in a country are equipped with sensors and continuously report data about the evolution of their structure. He then described research funded by Bosh where each appliance has a recognisable signature in order for the end user to see the energy consumption and use cost of the appliance. The system is intended to be interactive and provide users with suggestions on how to change their consumption habits. Five homes in Pittsburgh are currently taking part in such a pilot programme. Two hundred sensors will also be deployed in two hundred houses through another programme involving the Carnegie Mellon Portugal Program and the University of Madera. The results of the programme will help identify what type of information – and how it should be provided – could help users change their behaviour to consume less energy.

35. **Patrick Grossetete**, a former Cisco IPv6 expert, presented the activities of ArchRock which develops and operates sensor networks to provide end-to-end communication between devices and applications based on IP technologies mainly for smart grid and smart metering. The use of IP technologies prevents rapid obsolescence of current solutions and ensures that knowledge for development, maintenance, security and troubleshooting remains widespread. ArchRock concentrates on energy monitoring in commercial and industrial buildings to get real time information for energy consumption. To sell such products, benefits have to be obvious: the key selling points are money savings (many studies show that 8% to 12% of energy can be saved by changing people's behaviour) and buildings benchmarking

(with an increased environmental quality, the building's carbon footprint can be advertised and renting and selling prices can be raised in proportion to energy savings).

36. **Verena Weber**, Consultant to OECD, chair of Business-to-Business Marketing at WHU Otto Beisheim School of Management, introduced the OECD report on sensors, sensor networks and the environment which focuses on the enabling role of sensors. The report focuses on smart grids, smart buildings, smart transportation, smart industrial applications and precision agriculture, and reviews existing studies. The main outcomes are that sensors provide measurement data that can contribute to providing transparency, which is useful to changing user behaviour; the study also showed a positive impact of sensors and ICTs in general in most fields of application, apart from transportation where the overall effect is unclear due to rebound effects caused among others by Intelligent Transportation Systems (ITS). The main challenges include lack of standards, handling of a tremendous increase in data volume, as well as important upfront investments in some fields of applications. Policy issues for discussion include the necessity of a holistic and transparent measurement model taking all effects into account, integration and co-ordination, public-private co-operation for further R&D, relationships between ICT policy and environment policy, government demand for green technologies and government promotion of sensor technology by acting as first user.

Discussion:

37. The discussion highlighted the following points:

38. *Complexity, scalability and cost to be addressed*: efficient sensor networks require taking into account a long list of parameters and it is necessary to be aware of the possible effects and drawbacks of sensor networks deployments. Complexity can easily become a serious challenge. Scalability is also a key concern as climate change and other environmental concerns are generally global. Customers are looking for scalable and affordable applications that can interact with their existing environment, with near term outcomes. There is a demand for turnkey integrated solutions to help with energy efficiencies, but those are very costly and limited to specific firms (*e.g.* energy companies). In other areas, the cash flow is not sufficient. In these cases, solutions need to be scalable and cost neutral through energy savings. It is possible that technology breakthroughs emerge from the industrial sector where there seems to be a more sustainable business model. Such breakthroughs would benefit other areas later.

39. *Role of government:* there is consensus that governments need to be proactive, for example by funding more research and providing incentives and disincentives (*e.g.* tax incentives, CO2 requirements). The pressure could come from making waste, such as water leaks, costly; to force businesses to care about it; and to enable new business models. Environmental assessments, where negative, positive and rebound effects are identified and measured, are essential. The nature of government involvement often depends on the specificities of each area (*e.g.* Australia is monitoring the Barrier Reef impact due to its impact on tourism). Therefore, in these cases, policy is likely to be more relevant at national or regional level than through more global approaches.

Session 3: Transportation

40. Session three was moderated by **José Viegas**, from Instituto Superior Técnico, Portugal (currently in charge of MIT-Portugal / Transportation Systems)..

41. **Assaf Biderman** presented several projects of the MIT SENSEable City Laboratory which examine how cities are changing and explore new types of urban design. Citymotion analyses the trajectories of tourists in New York and Lisbon over time through user-generated content (Flickr data sets) and aggregated mobile phone network activity logs. Transportation data and analysis measure urban

accessibility using GPS trajectories. Another project collects real-time information about environmental conditions, such as air quality, via sensors mounted on bicycles and will be deployed in 2010 in Copenhagen.

42. **Martin Böhm**, from Austria tech, described the Coopers project, co-founded by the EC. The concept is a road traffic monitoring system: the Co-operative Systems for Intelligent Road Safety connects vehicles via continuous wireless communication with the road infrastructure on motorways. It exchanges data and information relevant for the specific road segment to increase overall road safety and to enable co-operative traffic management. Coopers collects positions and status such as indicators for slippery roads or dangerous situations, information from vehicles on the road and feed orders ("decrease speed", "use of the right lane"). This information is used to warn other vehicles in real time that dangerous situations might be ahead.

43. **Augusto Casaca**, from the Lisbon Technical University, presented the SafeGround project which aims to monitor ground activities at airports by including a location sensor GPS/EGNOS on each vehicle. The data is collected by sensor boxes and provides position information on every vehicle in the airport ground which can then be displayed on an airport map and be used to prevent accidents. The communication of the sensor boxes with the central system relies on WiFi or WiMax. Eventually, this technology will be adapted to the road context, leading to improved safety and avoidance of accidents. The awareness and responsibility of drivers should increase and the technology could adapt to drivers' profiles.

44. **A. Luís Osório,** Institute of Engineering of Lisbon, explained how electronic license plates would enable vehicles to always be connected through intelligent infrastructures (Brisa). Since 2002, a new strategy was developed to extend the business model of automatic tolling systems (Via-Verde) to the payment of parking, gas-stations, insurance, etc. This meant going from a monolithic/mono-vendor solution to a multi-suppliers integrated solution with a holistic approach from sensors to processes. Collaborative frameworks are necessary to realise electronic-based co-operation in contexts where one organisation's processes are dependent upon processes from other organisations. Open integrated and standard-based solutions are developed enabling evolving, multi-technology, scalable, fault tolerant, secure and auditable systems.

45. **José Viegas** noted that many projects involving sensor networks have already been launched, some more than 10 years ago, like intelligent bus lanes where lanes become bus lanes only if a bus is in it. He mentioned other initiatives, such as shared taxis, a taxi transporting several persons going in the same direction which would cost less for each passenger, emit less CO2 and reduce traffic. Shared taxis could bring benefits but are not being implemented. The technology is there, but not used because this service is not allowed by the existing regulation. Other promising projects include live reconfiguration of public transport plans where led-based traffic lights become screens and provide traffic advice. Another MIT-Portugal project aims to enable or limit car functionalities based on data about the driver's ability as well as the weather, road and traffic conditions. Changing drivers' capacity (*e.g.* limiting speed in a given context) could help prevent most common car accidents.

Discussion

46. The discussion highlighted the following points:

47. *Security, liability and privacy to be considered*: vehicle information systems strongly rely on wireless communication networks which are often vulnerable to attacks. Furthermore, devices distributed in vehicles will not be controlled anymore and, in the absence of appropriate security controls, could be manipulated. However, smart transportation systems are at a stage of development where research teams are mostly concerned with proving that their systems work: security comes after. In addition to technical

security measures, operational security management issues are also important. Many systems will not be monolithic but rather co-operative: the data will flow through various communication and information systems. Therefore security needs to be managed carefully through models encompassing the information lifecycle and including audit measures. Liability issues may lead to keeping the data collected longer than expected, in a secure manner, to prevent it from being manipulated. Broad public discussion might be needed to discuss privacy issues, especially given that different countries will have different legal frameworks and technology solutions will have to adapt.

48. *Technology is advanced but cost and user acceptance are key*: a number of the projects mentioned in the session are already in use (Brisa, SafeGround, etc.) and others are about to be launched such as Coopers. However, all these examples are from the supply side, aligned with the commercial interests of the infrastructure provider and it will be much harder to have a real penetration for projects in relation with end users. Readiness is not the main problem as most of the technologies are well advanced, but cost and acceptance are key. Some projects based on users' behavioural data could benefit from data generated by utilities. Some projects require a minimum number of end users to be equipped and their efficiency increases with the number of equipped users. The efficiency of other projects, based on users making decisions based on privileged information, decreased with a larger number of equipped users.

49. *The role of government:* ICT R&D demands large investments and a project often takes 20 years from the concept to a useable product. Generalised subsidies for public transport rather than multilevel services may be seen as an obstacle for investments in innovative improvement.

Session 4: Policy discussion

50. The last session, moderated by **Manuel Pedrosa de Barros**, Director of the Communication Security Office of ANACOM, focused on the main findings of the discussion among the experts with a view to highlighting whether and how governments could help to stimulate innovation, overcome challenges, and foster the development of sensor-based networks where they are most needed and most promising.

51. *Health and elderly care*: **Elettra Ronchi** noted that sensor networks and electronic medical networks are expected to not only decrease the costs for health care but also to improve quality of life for elderly people and to provide more accurate and timely information on the health status of a patient. Areas of application include chronic disease management, preventative health, patient safety, medication adherence, mobility affecting degenerative diseases. Sensor networks could help reduce hospitalisation and delay transition to long-term care facilities. Leveraging existing technologies, numerous ongoing pilots highlight that the *technology is generally mature* apart from biosensors that are less mature and in need of funding. However, *scalability* largely depends on standards-setting, ability to integrate with other systems, commercial drivers and appropriate incentives as there is a lack of business models. Cost is also an important variable. Patients' and provider's *acceptance* of the technology is essential for its development. Remote patient monitoring relies on changes in the usual workflow, special issues arise in systems where physicians are payed fee-for-service and hospital revenues or employment could be impacted. Closed (*e.g.* hospital) and open systems will lead to different *economic models*. Although some models, often based on cost-avoidance, are emerging, their long-term sustainability is unknown. Ultimately, consumers' willingness to pay will be key and more evidences of cost-effectiveness will be needed to convince public and private payers. Health is a special sector where there is a significant misalignment of incentives. *Government actions* are needed *i)* to drive the industry to implement interoperable solutions, as well as to educate and facilitate organisational change; *ii)* to fund R&D and *iii)* to facilitate interdisciplinarity, interoperability and open systems. *Privacy and security* raise issues of access and data ownership, in particular in the home care context and with regards to location data. However, many users might be willing to accept some loss of privacy in exchange for increased safety (*e.g.* with wearable fall sensors).

Privacy and Security should be embedded at design stage. Finally, in a health context, the acquisition of data will need to be accurate and meaningful and its processing within a clinical context could require complex regulatory constraints.

52. *Protection of the environment*: **Graham Vickery** explained that sensor networks improve environmental performance across many critical areas (such as climate change, global warming, energy efficiency, non-energy resource depletion, land use, water use, biodiversity, etc.) and in many activities (R&D and design, manufacturing, distribution, use, and disposal). There is a high diversity of sensor applications for various kinds of environmental challenges such as environmental monitoring, precision agriculture, industrial applications, housing, transport, smart metering, and smart grids. There is a clear distinction between commercial *applications driven by market considerations* (*e.g.* smart buildings, industrial applications) *and applications related to public good* where benefits accrue to all and costs are borne by a few (*e.g.* monitoring oceans) and where market failures are more likely. Understanding complex systems requires a *holistic approach*, encompassing the value chain, looking at all costs and benefits and taking into account possible rebound effects. *Behavioural changes will be key*. *Scalability and lack of standards* are challenging issues. The lack of bandwidth could be an obstacle in some areas for example where video is required. *Privacy* could be an issue in some areas (*e.g.* sensor data revealing human activity). *Governments have a role to play* by *i)* leading by example (*e.g.* funding development of infrastructures, early adoption of technologies; funding R&D and education) ; *ii)* adopting forward-looking outcomes based regulation (*e.g.* reduce CO2 by X) to encourage sensor applications while remaining technology neutral; *iii)* turning taxes into incentives.

53. *Transportation*: **José Viegas** noted that a potential for strong efficiency gains for *the supply-side* (infrastructure providers and transport services) could lead to the introduction of sensor applications on the market. On the *customer side*, several challenges arise such as the need for a minimum number of adopters for applications to be useful (network effect). Most of the *technologies are ready* and available but *organisational issues and technical integration* are challenging. Many applications start as proprietary, over closed networks, but real consumer-oriented inter-modality raises the need for *open networks and interoperability*. For most applications, bandwidth is not an issue. Increased convenience often implies tighter tracking of individuals possibly leading to privacy challenges, although the *balance between convenience and privacy* is still unknown. *Liability* issues are not clear when the service consists in giving advice to travellers and not of automatic actions or decisions. Discrepancies with respect to legal frameworks (*e.g.* privacy, liability) across borders might be challenging. With regards to public transports, indirect subsidisation prevents market segmentation through optional services and might prevent innovation. Similarly, most price schemes in transport are biased, forcing business models to be biased too, and making investment riskier. Technological obsolescence can also be seen as a source of risk for investors, although good modular design can address this concern. *Governments* could promote development and demonstration of new applications (especially intermodal ones), forcing utilities to share data, and allowing standards to emerge. They could also encourage discussion related to privacy protection and introduce gradual change in pricing regimes of transport systems, promoting rational support to efficiency, equity and sustainability.

54. **Manuel Pedrosa de Barros** thanked the moderators for the clarity of their summary of the social and economic opportunities and challenges, benefits, drivers and obstacles associated with the development of sensor networks applications in the different sectors considered. Suggestions related to how the different stakeholders, governments in particular, could help increase innovation and its positive impact on society, the environment and the economy were of particular interest for the OECD.

55. **Gérald Santucci** (European Commission, Directorate General Information Society and Media), **Alessandra Pierucci** (Data Protection Authority, Italy) and **Andreas Krisch** (Civil Society Information Society Advisory Council, European Digital Rights) focused their comments on the issue of *user trust* and

the need for *dialogue* among all stakeholders. They highlighted the variety of sensor technologies, applications, and implications as well as the differences in terms of maturity and readiness of the technology across sectors and stressed the importance of data protection in every field of application for sensor networks. The success of any network mainly depends on its *acceptance*, and it will only be accepted if trusted. Therefore, open *dialogues with stakeholders* are essential to understand all the possible concerns, privacy in particular. Moreover, the implementation of proper measures for the *protection of personal data before the deployment* of sensor networks straight from the outset of each project is necessary to create sufficient trust. Privacy issues are specific to each sector and to each country and ethical frameworks will be needed in addition to legal ones. It is important to avoid the rejection of projects due to a lack of information and clarity, especially as research, development and deployment of sensor networks have been evolving quickly in the past few years and as this trend will only increase.

56. **Anne Carblanc**, from the OECD Secretariat, noted that the discussion had brought a wealth of information on many sensor networks applications at a pilot or small-scale implementation stage in different sectors. In most cases, it remained unclear if deployment would occur at a five-, ten- or fifteen-year horizon. Several technical, legal and economic challenges had been identified and would be summarised in the Chair's concluding remarks. Because we may long have had a sense that ICTs drive developments in our societies, one question to ask ourselves was: at the beginning of new developments that may lead to an "Internet of Things", do we know what future we want to build? Do we identify our society's needs properly? For what exactly should we need to foster the development of sensor networks?

Conclusion

57. The Conference Chair, **Luis T. Magalhães**, thanked all participants for a very interesting discussion. Sensor networks cover a wide variety of applications and technologies the economic and social implications of which require specific consideration for each particular application as well as a fully interdisciplinary and multi-stakeholder approach.

58. Clearly, *technology* has come a long way in recent years. But if technologies are mature, they are still fragmented so that scaling up, interoperability and horizontal standards are still unsolved issues. With respect to standards and to stimulate innovation, a pragmatic and technology-neutral approach could be to consider a few application areas with technology commonalities rather than trying to encompass all areas of potential development.

59. Mr. Magalhães noted that *business models* are in different stages of viability for different applications. For example, people-centred applications like the personal health information systems, seem to lack a sustainable business model except where a clear cost reduction approach can be identified, *e.g.* to decrease hospital admissions. Benefits are expected in the medium to long range and will be effective only if they are aggregated at a large scale. Therefore to be sustainable, business models will probably require some sort of aggregation of demand. For example, it will be important to involve as early as possible the main investors in health systems, namely *i.e.* major health insurance companies and national public health systems. Business models for applications in the environment area, where benefits are often seen as a public good, will need government and civil society involvement for building up investment frameworks. Public-private partnerships will have a role to play due to industry interests in developing the necessary technologies. But these entities will also need to be engaged in the implementation of measures to reduce environmentally aggressive activities. This may allow decentralising demand and building up a dynamic market for innovative environment protection technologies. Potential benefits are clear although careful environmental analysis will be needed on a case-by-case basis. Many of those remarks also apply to transportation and energy efficiency applications that were not explicitly considered in the chosen thematic sessions but are related to environment and transportation.

60. Mr. Magalhães also mentioned the need to involve *users* and to consider their concerns in the project development phases, which were raised for most of the applications presented in the Conference. In particular, privacy and security concerns seem to have been often underestimated at the early stages of development. Risk and liability issues were not much discussed, but they certainly need more attention in several applications.

61. After commenting on the Secretariat document presenting an overview of the discussions (see Annex II), he stressed that, although the complexity of the issues in sensor networks applications seems overwhelming, there are many reasons to believe that this area will continue to evolve quickly. Most of the problems identified require more expertise and research, but solutions will not occur simply over time. More efforts will need to be put into organising and clarifying policy avenues.

ANNEX I: OVERVIEW OF THE DISCUSSION

Conclusions - 1

- **Sensor networks offer potential benefits:**
  - Health (chronic disease management, reduction in hospitals' costs)
  - Environment (monitoring, precision agriculture, smart grids, industrial applications)
  - Transport (efficiency gains for supply-side (infrastructure providers and transport services) leading to the introduction in the market and for customers)
  - **Technology: heterogeneous – mainly in demo or trials**
  - Many basic ingredients are ready and available in the market (cell phones, algorithms)
  - Difficulties are mainly associated with technical integration and organisational issues (different lifecycles for infrastructure)
  - Sensor power is an issue
  - Biosensors are less mature than other sensors and in need of funding
  - Scalability of applications is an issue
  - Standards remain an issue.

Conclusions - 2

- **Potential market for sensor networks:**
  - The needs seem to exist (society or individual needs) but:
    - Willingness to pay by patient/consumer /citizen/organisations will be key in many applications
    - Investment and financing are not always there – depending on risks – ROI is generally uncertain
  - Most **business models** are based on cost-avoidance – but new ones are emerging that still need to be tested (*e.g.* Data aggregation and profiling)
    - Currently cost seems to outweigh benefits in many applications
    - Where there is cost reduction or where systems can be distributed: low risk and business models can be sustainable.

Conclusions - 3

- **A key issue is data/information management**
  - What data can be processed by sensor networks?
    - The more convergence of data originating from different sources (sensed data, location-based information – GPS, climate…), the bigger the issue – privacy and security
    - The more users who can access the data, the bigger the issue – privacy and security
    - Another key issue is **legal liability**
- **Multidisciplinarity** should include involvement of users, privacy and security experts from early stages of development to deployment

(it would foster building in requirements from the outset rather than after the fact and have a positive impact on acceptance).

Conclusions - 4

Should governments intervene? To do what?

- **Funding for R&D?**
- **Reviewing economic incentives?**
  - Health
    - Special sector – significant misalignment of incentives
  - Environment
    - Market failures (public goods)
  - Transport
    - For public transport, subsidisation of service affects innovation and may prevent market competition
- **Providing guidance for implementation of privacy and security?**
- **Fostering interoperability / open source?**
- **Other?**

Report to OECD and consideration of possible action in the context of the Innovation Strategy.

ANNEX II: LIST OF SPEAKERS WITH FULL TITLES

Lisbon, Portugal
08-09 June 2009

Mr. Joao Oliveira BARROS	*National Director* *Carnegie Mellon Portugal Program* *Portugal*
Mr. Assaf BIDERMAN	*Associate Director* *MIT SENSEable City Lab* *United States*
Mr. Martin BÖHM	*Senior Project Manager* *AustriaTech – Federal Agency for technological Measures LTD* *Austria*
Mme Anne CARBLANC	*Principal Administrator (Information security and privacy, Consumer Policy)* *STI/ICP* *OECD*
Mr. Augusto CASACA	*Professor* *INESC-ID/IST* *Portugal*
Mr. Dooho CHOI	*Senior Researcher* *Electronics and Telecommunications Research Institute* *Korea*

Mr. Mikael EKLUND	*Assistant Professor* *University of Ontario Institute of Technology* *Canada*
Mr. Keith ERREY	*CEO* *Toumaz Technology Limited* *United Kingdom*
Ms. Deborah ESTRIN	*Professor / Director* *UCLA / CENS* *United States*
Mr. Florent FREDERIX	*Scientific Officer,* *Head of Sector, Information Society and Media* *European Commission*
Mr. Patrick GROSSETETE	*Technical Director* *ArchRock* *France*
Mr. Dominique GUELLEC	*Principal Administrator (Patents, productivity analysis)* *STI/EAS* *OECD*
Mr. Hans-Christian HAUGLI	*Senior Vice President, Head Telenor Research and Innovation* *Telenor* *Norway*
Mr. Jiri HOMOLA	*Head of Photonics Division and Chairman of Department of Optical Sensors* *Institute of Photonics and Electronics AS CR, v.v.i.* *Czech Republic*
Mr. Masaru KITSUREGAWA	*Professor. Ph.D.* *Institute of Industrial Science, the University of Tokyo* *Japan*

Mr. Andreas KRISCH	*President* *European Digital Rights (EDRi)* *Belgium*
Mr. Luis MAGALHAES	*Vice-Chair OECD ICCP Committee* *President of the Knowledge Society Agency (UMIC)* *Ministry of Science, Technology and Higher Education* *Portugal*
Ms. Theresa MAURY	*Member of the Board* *ANACOM* *Portugal*
Mr. A. Luis OSÓRIO	*Coordinator Professor* *ISEL* *Portugal*
Mr. Manuel PEDROSA DE BARROS	*Vice-Chair of OECD WPISP Working Party* *Director* *Gabinete de Seguranca das Comunicacoes* *ICP-ANACOM* *Portugal*
Mrs. Alessandra PIERUCCI	*International Affairs* *Data Protection Authority* *Italy*
Ms. Elettra RONCHI	*Administrator (Health Information and Communication Technologies)* *ELS/HD* *OECD*
Mr. José Luís SANTOS	*Professor* *University of Porto* *Portugal*
Mr. Gérald SANTUCCI	*Head of Unit – Networked enterprise & RFID* *European Commission*

Mr. Karsten SCHISCHKE	*Senior Researcher* *Fraunhofer Institute for Reliability and Microintegration* *Germany*
Ms. Rebecca SIMPSON	*Director* *AO Action* *Germany*
Mr. Lucio SOIBELMAN	*Professor* *Carnegie Mellon University* *Portugal*
Mr. Graham VICKERY	*Principal Administrator (Information economy)* *STI/ICP* *OECD*
Mr. José VIEGAS	*Professor* *CESUR* *Instituto Superior Técnico* *MIT-Portugal Program, Transportation Systems* *Portugal*
Miss Verena WEBER	*Consultant to OECD,* *Chair of Business-to-Business Marketing at WHU Otto Beisheim School of Management* *Germany*
Mr. Darrell WILLIAMSON	*Deputy Director, Research Programs* *ICT Centre* *CSIRO* *Australia*
Ms. Beth WOZNIAK	*President* *Honeywell Sensing and Control* *United States*