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An Overview of Smart Sensor Technology

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Introduction

A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance. They are now used in many industrial and civilian application areas, including industrial process monitoring and control, machine health monitoring, environment and habitat monitoring, healthcare applications, home automation, and traffic control.

In addition to one or more sensors, each node in a sensor network is typically equipped with a radio transceiver or other wireless communications device, a small microcontroller, and an energy source, usually a battery. A sensor node might vary in size from that of a shoebox down to the size of a grain of dust, although functioning "motes" of genuine microscopic dimensions have yet to be created. The cost of sensor nodes is similarly variable, ranging from hundreds of dollars to a few pennies, depending on the size of the sensor network and the complexity required of individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and bandwidth. A sensor network normally constitutes a wireless ad-hoc network, meaning that each sensor supports a multi-hop routing algorithm (several nodes may forward data packets to the base station).

Sensor networks are the key to gathering the information needed by smart environments, whether in buildings, utilities, industrial, home, shipboard, transportation systems automation, or elsewhere. Recent terrorist and guerilla warfare counter measures require distributed networks of sensors that can be deployed using, e.g. aircraft, and have self-organizing capabilities. In such applications, running wires or cabling is usually impractical. A sensor network is required that is fast and easy to install and maintain. Smart environment represent the next evolutionary development in building, utilities, industrial, home, shipboard and transportation systems automation. Like any sentient organism, the smart environment relies first and foremost on sensory data from the real world. Sensory data comes from multiple sensors of different modalities in distributed locations. The smart environment needs information about its surroundings as well as about its internal workings; this is captured in biological systems.

The challenges the hierarchy of: detecting the relevant quantities, monitoring and collecting data, assessing and evaluating the information, formulating , meaningful user displays and performing decision – making and alarm functions are enormous. The information needed by smart environment is provided by distributed wireless sensor networks which are responsible for sensing as well as for the first stages of the processing hierarchy. The figure below shows the diagram of a typical architecture of a sensor node

Fig 1 an architecture of a sensor node

Fields of application of wireless sensor networks

There are numerous different fields of application of sensor networks. For example, forest fires can be detected by sensor networks so that they can be fought at an early stage. Sensor networks can be used to monitor the structural integrity of civil structures by localizing damage for example in bridges. Further, they are used in the health care sector to monitor human physiological data (Verdone *et al.*, 2008). The following sections outline selected applications of wireless sensor networks.

Smart buildings

Smart buildings are a field closely linked to smart grids. Smart buildings rely on a set of technologies that enhance energy-efficiency and user comfort as well as the monitoring and safety of the buildings. Technologies include new, efficient building materials as well as information and communication technologies (ICTs). An example of newly integrated materials is a second façade for glass sky scrapers. There are advanced ICT applications as well as a ceramic sunscreen consisting of ceramic tubes which reflect daylight and thus prevent the skyscraper from collecting heat. They are used in:

- Building management systems which monitor heating, lighting and ventilation
- Software packages which automatically switch off devices such as computers and monitors when offices are empty (SMART, 2020) /p>
- Security and access systems.

These ICT systems can be both found at household and office level. Furthermore, according to Sharpels *et al*., (1999), first-, second- and third-generation smart building systems can be distinguished as follows:-

First-generation smart buildings are composed of many stand-alone self-regulating devices which operate independently from each other. Examples include security and HVAC systems.

In second-generation smart buildings, systems are connected via specialized networks which allow them to be controlled remotely and “to facilitate some central scheduling or sequencing” (Sharpels *et al.,* 1999), *e.g.* switching off systems when rooms and offices are not occupied.

Third-generation smart building systems are capable of learning from the building and adapting their monitoring and controlling functions. This last generation is at an early stage.

Sensors and sensor networks are used in multiple smart building *applications*. These include:

- Heating, ventilation, and air conditioning systems (HVAC)
- Lightning
- Shading

- Air quality and window control
- Systems switching off devices
- Metering (covered in the section on smart grids)
- Standard household applications (*e.g.* televisions, washing machines)
- Security and safety (access control).

The figure 1 below shows the diagram of a typical wireless sensor network, which shows so important parts.

Fig2 **Typical wireless sensor network**

Transport and logistics

Information and communication technologies (ICTs) and sensor networks in particular have the potential to contribute to increased efficiency in freight and passenger transport as well as a potential reduction of overall transportation. On the one hand, increased use of ICTs can avoid freight and passenger transport through a higher degree of virtualization, digitization and teleporting. Digital content is delivered electronically and virtual conferences and teleporting reduce passenger transport. On the other hand, increased use of ICTs can contribute to better management of transport routes and traffic, higher safety, time and cost savings as well as reductions of CO2 emissions. Sensors and sensor networks play a vital role in the increase of transport efficiency. For example, sensor technology contributes to better tracking of goods and vehicles which might result in lower level of inventories and thus energy savings from less inventory infrastructure as well as a reduced need for transportation (Atkinson, Castro, 2008). Furthermore, sensors and sensor networks are pivotal parts of many intelligent transportation systems (ITS).

An intelligent transportation system (ITS) can be defined as “the application of advanced and emerging technologies (computers, sensors, control, communications, and electronic devices) in transportation to save lives, time, money, energy and the environment” (ITS Canada, 2009). The ITS can be categorized into *intelligent infrastructure* and *intelligent vehicles* (RITA, 2009). Many of these applications are based on sensors and sensor networks. In the field of *intelligent infrastructure* sensors in pavements are used for road traffic monitoring systems to measure the intensity and fluidity of traffic (vehicle count sensors) and to provide information for traffic lights which are then controlled. These sensors are further able to detect whether, for example, public buses are approaching so that the green phase of traffic lights can be extended, allowing buses to keep their schedules (Veloso, Bento, Câmara Pereira, 2009). They also transmit information to update public transport panels. New sensor applications include intermittent bus lanes. In addition, sensors are used for motorway tolling purposes where they detect vehicle RFID tags and retrieve the required information. Sensors also monitor the state of physical infrastructures such as bridges by detecting “vibrations and displacements”.

Precision agriculture and animal tracking

Sensors and sensor networks are important components of precision agriculture which aims at "maximum production efficiency with minimum environmental impact" (Taylor and Whelan, 2005). Land over-exploitation, one of the major concerns of intensive agriculture, leads to problems such as soil compaction, erosion, salinity and declining water quality (Wark *et al*., 2007). Sensors and sensor networks play a critical role in measuring and monitoring the health of the soil and water quality at various stages, from pre- to post-production. In the field of animal tracking, the movement of herds, the health of animals and the state of the pasture can be controlled via sensor networks. So far a number of sensor network systems have been developed and trials and field experiments are under way. However, concrete applications are at an early stage. This section briefly describes applications of sensor networks in precision agriculture and animal production. Subsequently, environmental impacts are presented qualitatively rather than quantitatively due to the early application stage. In precision agriculture, sensor networks can be used for:

- Plant/crop monitoring,
- Soil monitoring,
- Climate monitoring and
- Insect-disease-weed monitoring.

In the field of plant/crop monitoring, wireless sensors have been developed to gather, for example, data on leaf temperature, chlorophyll content and plant water status. Based on these data, farmers are able to detect problems at an early stage and implement real-time solutions. The health and moisture of soil is a basic prerequisite for efficient plant and crop cultivation. Sensors contribute to real-time monitoring of variables such as soil fertility, soil water availability and soil compaction. Further, sensor nodes which communicate with radio or mobile network weather stations provide climate and micro-climate data. Sensors registering the temperature and relative humidity can contribute to detect conditions under which disease infestation is likely to occur.

The health of pastures can also be evaluated through high-resolution remote sensing tools. Healthy pastures usually "has a consistent cover of evenly dispersed perennial vegetation" (Ludwig *et al*., 2008). Remotely sensed satellite maps depict the location of persistent vegetation cover. Based on this information and information on the three dimensional shape of the landscape, as a scientists it is possible to calculate the leakiness values and their changes over time. As a result, conditions of pastures can be measured and problematic areas detected (Ludwig *et al*., 2008).

Wireless sensors are further used for precision irrigation, and systems developed for remotely controlled, automatic irrigation. Sensors assume, for example, the tasks of irrigation control and irrigation scheduling using sensed data together with additional information, *e.g.* weather data (Evans and Bergman, 2003). Finally, sensors are used to assist in precision fertilization. Based on sensor data, decision support systems calculate the "optimal quantity and spread pattern for a fertilizer" (Wang *et al*., 2006). Wireless sensor networks also contribute to a better understanding of the behavior of cattle, such as their grazing habits, herd behavior and the interaction with the surrounding environment (Wark *et al*., 2007). The information provided by these sensors helps farmers to understand the state of the pasture and to find optimal ways to use these resources. To test sensor applications for cattle management, Wark *et al,* (2007) attached sensor nodes to cattle collars. Sensors communicated in a peer-to-peer fashion. Cattle collars pinged each other “with each ping containing an animal’s GPS position and time of each ping transmission” (Wark *et al.,* 2007). Based on the positioning data of each node and inertial information, the cattle’s individual and herd behavior could be modeled and more general models could be developed. As a result, farmers are able to optimally manage environmental resources and plan grazing areas to prevent environmental problems such as overgrazing and land erosion. Current work focuses on the integration of sensor networks and radio frequency technology (RFID) as a significant number of cattle are equipped with RFID tags to record their ID as well as information such as cattle characteristics and food information.

Environmental monitoring

In environmental monitoring in the areas of water pollution, air pollution, analysis of global warming, as well as facilitated recycling. Sensor networks are deployed in *waters* to monitor the *level of pollution* as well as the state of marine life. Along the entire Hudson River in New York, scientists are installing sensors nodes which will partially be suspended from buoys. Data is transmitted wirelessly and provides information about current pollution levels. For *air pollution monitoring*, sensor networks are deployed within cities in order to detect specific times and locations when pollution peaks. Engineers from Harvard University deployed 100 general purpose nodes onto streetlights to cover the city of Cambridge, L. A. aiming at measuring the amount of particles in the air and collecting weather data. The sensors are directly powered by the city streetlights and communicate via Wife radios (Greene, 2007).

The *analysis and assessment of global warming* requires sophisticated IT technology to understand to which extent and why the climate has changed. Some applications involve sensor networks. For instance, a plane which is deployed in the arctic by the National Oceanic and Atmospheric Administration researchers is equipped with 30 airborne sensors and collects “data that can be used to produce a detailed simulation of the chain of chemical reactions that arctic pollution cause and that increase ice melting” (Atkinson, Castro, 2008). Furthermore, a worldwide sensor network, the Global Earth Observation System of Systems (GEOSS) is currently being developed with the aim to collect data relating to climate change and more generally air pollution. .

In the *collection and recycling of waste* an automatic sorting machines are not only equipped with magnets to sort out metal objects but also with optical sensors. These sensors identify different kinds of plastics and paper allowing them to be put in different bins. Furthermore, RFID tags with integrated sensors on private households’ bins measure the weight of the waste. Costs are then allocated according to the weight of the waste during the year.

Urban terrain tracking and civil structure monitoring

This field of application covers the structural health monitoring of large civil or urban structures. One prominent example is the Ben Franklin Bridge. A network of ten sensors monitors the strain of the bridge structure when trains are crossing the bridge. Two different operation modes reduce the required power: a low-power sampling mode checks if any trains are passing. If this is the case, the strain increases and leads the system to switch to a second mode in which samples are collected at a higher pace to monitor precisely changes in the strain.

Entertainment

Multiple different and heterogeneous applications are conceivable in the entertainment area. According to Verdone *et al.* (2008), there are application scenarios in which live TV shows react to user (emotional) feedback. This enables viewers to get more involved in the shows and the provider to adapt the shows more to the viewers' needs. Further examples include applications in the games area: Via sensor networks, game players are able to project their moods and gestures in the virtual world.

Security and surveillance

Security and surveillance sensor networks are used in the military and defence area, for example for the surveillance of borders. In this case, different kinds of sensors are used, ranging from sensors monitoring temperature to sensors monitoring light to acoustic sensors. Further, they are also employed for civil structure, for instance for fire detection systems in buildings.

Health care

Sensor networks can be and are currently used in multiple ways in the healthcare sector. Applications cover Tele-monitoring of patients' state of health, tracking and monitoring the movements of patients and doctors, drug administration and diagnostic applications (Heppner, 2007, Verdone, 2008). In the field of patients' state of health, sensor networks are particularly useful for patients under medical observation. Sensors communicate gathered data to a telecommunication device such as a mobile phone, which further transmits the data to nurses' or doctors' rooms in case of dangerous changes of the state of health. It is also possible to carry out medication control via these sensors (Heppner, 2007). Sensor networks and location-based services allow doctors to be quickly tracked in hospitals in case of emergency. The same principle is applicable to their patients. Furthermore, wireless sensors are developed for implants such as glaucoma sensors or intra-cranial pressure sensor systems (Healthy Aims, 2008).

Summary

Sensors and sensor networks have an important impact in meeting environmental challenges. Sensor applications in multiple fields such as smart buildings and smart industrial process control significantly contribute to more efficient use of resources and thus a reduction of greenhouse gas emissions and other sources of pollution. This report gives an overview of sensor technology and fields of application of sensors and sensor networks. It discusses in detail selected fields of application. The review of the studies assessing the impact of sensor technology and contribute to a reduction of emissions across various fields of application. Whereas studies clearly estimate an overall strong positive effect in smart buildings, smart industrial applications as well as precision agriculture and farming, results for the field of smart transportation are mixed due to rebound effects. In particular intelligent transport systems render transport more efficient, faster and cheaper. As a consequence, demand for transportation and thus the consumption of resources both increase which can lead to an overall negative effect.

This illustrates the crucial role governments have to enhance positive environmental effects. Increased efficiency should be paralleled with demand-side management to internalize environmental costs. Further, minimum standards in the fields of smart buildings in regard to energy efficiency can significantly reduce electricity consumption and greenhouse gas emissions. Finally, this report also highlights that applications of sensor technology are still at an early stage of development. Government programmes demonstrating and promoting the use of sensor technology as well as the development of open standards could contribute to fully tap the potential of the technology to mitigate climate change.

Conclusion

This report gives an overview of sensor and sensor networks applications and their impact on the environment. It discusses selected fields of application which have a high potential to tackle environmental challenges. It can be seen that a review of different studies assessing the environmental impact of ICTs and especially sensor and sensor networks reveals that these technologies can contribute significantly to more efficient use of resources. Government policies and initiatives are crucial in fostering the positive environmental effects of the use of sensors and sensor networks in different fields and are an essential part of strategies to radically improve environmental performance However, rebound effects have to be taken into account, and increased efficiency due to the use of sensor technology should be paralleled with demand-side management which internalizes environmental costs, for example by raising CO_2 –intensive energy and fuel prices. In the field of smart buildings, minimum standards of energy efficiency can be a major factor in reducing electricity use and greenhouse gas emissions.

In general many applications in promising fields are still at an early stage of development. Joint programmers and implementation projects can promote the use of sensor technology and contribute to industry-wide solutions and the development of open standards.

Finally, the use of ICTs and especially sensor technology is sometimes relatively expensive, for example in the agriculture and farming sector in terms of farmers' economic considerations. Governments can encourage the use of ICTs and sensor technology through conservation programmes and by accentuating the environmental dimension of ICTs in agriculture and farming.

References

Alberta Transportation (2009). "Intelligent Transportation Systems", www.transportation.alberta.ca/606.htm.

Atkinson, R. and D. Castro (2008). *Digital Quality of Life – Understanding the Personal & Social Benefits of the Information Technology Revolution*, Washington DC.: The Information Technology and Innovation Foundation.

Chong, Chee-Yee and Srikanta P. Kumar (2003). "Sensor Networks: Evolution, Opportunities, and Challenges", *Proceedings of the IEEE*, *91,* 8, 1247-1256.

Culler, D., D. Estrin and M. Srivastava (2004). "Overview of Sensor Networks", *Computer*, Washington, DC.: IEEE Computer Society 40-49.

Department of Energy, United States (DOE) (2004). *Industrial Technologies Program – On-Line Laser-UltrasonicMeasurement System*, Washington, DC.

Department of Energy, United States (DOE) (2002). *Industrial Wireless Technology for the 21th century*, Washington, DC.

Erdmann, L. (2009). *Development of a Framework and Overview Paper on ICTs and Environment*, OECD, working paper

Evans, R. and J. Bergman (2003). "Relationships Between Cropping Sequences and Irrigation Frequency under Self-Propelled Irrigation Systems in the Northern Great Plains, *USDA Annual Report*.

Green, K. (2007). "A Wireless Sensor City", *MIT Technology Review*, April 13th, MIT, Cambridge, MA.

Group on Earth Observations (GEO) (2008). Geo Members, www.earthobservations.org/ ag_members. html.

R. Jordan, R. and Abdallah, C.A. (2002). "Wireless communications and networking: an overview," Report, Elect. and Comp. Eng. Dept., Univ. New Mexico.

Kolesar, E.S., Brothers, C.P., Howe, C.P. et al. (1992). "Integrated circuit microsensor for selectively detecting nitrogen dioxide and diisopropyl methylphosphate," Thin Solid Films, *220*, 30-37.

Kumar, P.R. (2002). "New technological vistas for systems and control: the example of wireless networks," *IEEE Control Systems Magazine*, pp. 24-37.

Liu, K. Fitzgerald, M.and Lewis, F.L. (2002). "Kinematic analysis of a Stewart Platform manipulator," *IEEE Trans. Industrial Electronics*, *40*(2), 282-293.

Low, S.H., Paganini, F.and Doyle, J.C. (2002). "Internet congestion control," *IEEE Control Systems Magazine*., pp. 28-43.

Ray, S (2001). "An introduction to ultra wide band (impulse) radio," Internal Report, Elect. and Computer Eng. Dept, Boston University.

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