Title	Sensing the sensor web
Authors(s)	Wan, Jie, O'Grady, Michael J., O'Hare, G. M. P. (Greg M. P.)
Publication date	2012-03-19
Publication information	Wan, Jie, Michael J. O'Grady, and G. M. P. (Greg M. P.) O'Hare. "Sensing the Sensor Web." IEEE, March 19, 2012. https://doi.org/10.1109/PerComW.2012.6197529.
Conference details	Paper presented at Pervasive Computing and Communications Workshops (PERCOM Workshops) 2012, 19th March, Lugano, Switzerland
Publisher	IEEE
Item record/more information	http://hdl.handle.net/10197/3757
Publisher's statement	Personal use of this material is permitted. Permission from IEEE must be obtained for all other uses, in any current or future media, including reprinting/republishing this material for advertising or promotional purposes, creating new collective works, for resale or redistribution to servers or lists, or reuse of any copyrighted component of this work in other works.
Publisher's version (DOI)	10.1109/PerComW.2012.6197529

Sensing the Sensor Web

Jie Wan, Michael J. O'Grady, Gregory M.P. O'Hare
CLARITY: Center for Sensor Web Techonologies
School of Computer Science & Informatics, University College Dublin,
Dublin, Ireland.
Jie.Wan@ucdconnect.ie, {michael.j.ogrady,gregory.ohare}@ucd.ie

***Abstract*—The maturity of pervasive computing and Wireless Sensor Networks (WSNs) enables the development of smart environments in many scenarios, including surveillance and environmental monitoring. Extensive research efforts are being undertaken in sensor perception, data capture, management and interpretation. Such developments are a prerequisite for paradigms such as pervasive sensing and crowd-sourcing services. For mobile users, the issues of dynamic sensor discovery, data interpretation and visualization must be addressed if such services are to be realized in practice. This paper explores the genesis of a generic framework for heterogeneous sensor access and data visualization in remote contexts.**

***Keywords*-Sensor Networks, pervasive computing; data visualisation.**

I. INTRODUCTION

Wireless Sensor Networks (WSNs) are perceived as a fundamental enabling technology for smart environments. Such networks have been the subject of an intense research efforts in the last decade, and their potential has been documented in a variety of domains including surveillance, environmental monitoring and healthcare. Invariably, such networks use a variety of technologies that have been optimized to address many practical operational constraints. Thus, while sensors can route data via the Internet to centralized servers, interaction with individual sensor nodes and even subnets in a point-to-point fashion is practically impossible using conventional consumer technologies due to incompatible protocols, ontologies and semantics. It may be envisaged that enabling point-to-point access would enable a raft of mobile crowd-sourcing services, for example. Such an approach would augment existing applications which usually harness sensors embedded on the mobile device itself, and enable existing sensor web infrastructures be utilized by a wide variety of end-user groups.

II. RELATED RESEARCH

Heterogeneity is a key obstacle to seamless and instantaneous interaction with the sensor web. Sensors and mobile phones use different protocols, and adhere to different standards. The Internet itself can be harnessed to overcome these obstacles in many cases, should a connection exist. Thus in most cases, the model of centralized access dominates. Mote-View [1] is an exemplar case, being one of a number of documented efforts in this area. However, of more relevance to this discussion is interaction with WSNs while in the physical environment. Tricorder [2] is a dedicated device for browsing and navigating WSNs. It can query local sensor nodes directly or remote sensor nodes by issuing a multi-hop request. Ringwald et al. [2] have developed a tool for interactively inspecting WSNs in the field, allowing querying of individual nodes as well as topology viewing. Siorpaes et al. [3] have explored how mobile interaction with physical objects might occur, though with an emphasis on RFID as an enabling technology.

In the case of crowd-sourcing, some applications that harness sensors of various hues include crowd-sourcing geospatial data [4] and integrating web-based crowd-sourcing with the mobile phone platform [5]. In these cases, the sensors are invariably hosted on the mobile phone itself. Interacting with sensors embedded in the physical environment remains an outstanding challenge if pervasive sensing is to become a reality.

III. TOWARDS PERVASIVE SENSING FRAMEWORK

Two key technologies are fundamental to the pervasive sensing paradigm. Certain types of mobile phones are sufficiently powerful and robust to enable sensing, interpretation and visualization. Likewise, some pre-existing short-range networking technologies can be harnessed to enable pervasive interactions with suitable equipped sensor platforms.

A. Pervasive Platforms

Modern mobile phones integrate advanced computing capabilities and connectivity features; third-party applications and services can be easily integrated. From a connectivity perspective, a number of networking technologies and protocols are supported, including Wi-Fi, Bluetooth, RFID and so on. In contrast, sensor nodes tend to support a different suite of technologies with Zigbee being the dominant communications technology. However, more powerful nodes have appeared on the marketplace that support Bluetooth and WiFi, thus hinting that a overlap of technologies may materialise in the near future, all of which has significance for enabling practical pervasive sensing platforms.

B. Perceiving Sensors

Zigbee and Bluetooth are fundamental technologies for enabling sensor discovery and data transmission.

Zigbee is the key wireless communication technologies harnessed by WSNs. It incorporates a high level communication protocol, using small, low-power digital radios, which attempts to realise a low data rate, long battery life and secure network environment. It is simple and cheap, characteristics that have contributed to its popularity for WSNs. However, mainstream handset manufacturers as yet have not seen fit to include Zigbee as standard on their suites of mobile devices.

Bluetooth is a universal radio interface, based on the 2.45 GHz frequency band, that enables portable electronic devices of various hues to be interconnected and thus communicate with each other via short range, ad-hoc networks. Bluetooth has been integrated into a wide range of devices, including mobile phones, headsets, printers, projectors and various embedded computing platforms. It is a packet-based protocol with a master-slave structure upon which the master can communicate simultaneously with up to 7 slaves in a piconet, without a need for user intervention. Bluetooth specifications are developed and licensed by the Bluetooth Special Interest Group (SIG), which consists of more than 13,000 companies in the areas of telecommunication, computing, networking, and consumer electronics.

C. Interpreting Sensor Data

A standardised approach to sensor and service discovery is a prerequisite for enabling seamless interaction between mobile devices and embedded sensor networks. Much research has taken place in these areas, though not, it should be stressed, with the intention of addressing this objective. Sensor Model Language (SensorML) [6] is one initiative of particular interest. This specifies a standard encoding for sensor metadata descriptions, which forms the basis for delivering the metadata to facilitate discovery. In addition, SensorML also offers a mechanism for sensor data interpretation and analysis, therefore it can be harnessed for broad sensor registry and populating activities. SensorML is encoded as an XML schema, and seeks to encompass as broad a range of sensor platforms as possible. However, its ubiquity becomes a handicap when dealing with light, mote-type wireless node platforms, as these possess significantly less computational resources; thus including this metadata over a Zigbee connection may significantly slowdown the data transfer, while consuming the already scarce power resource. One initiative for mote-type platforms is MoteML [7]. This specifies a light-weight mechanism for sensor metadata encoding, where only fundamental elements are presented. MoteML is designed using a text-based approach, and it is thereby more suitable for memory constrained devices of the mote class.

In the following case study, we present a prototype of an adaptive sensor browser, which offers the functionality of pervasive sensor discovery, data interpretation as well as adaptive visualisation. For this study, a simplified XML

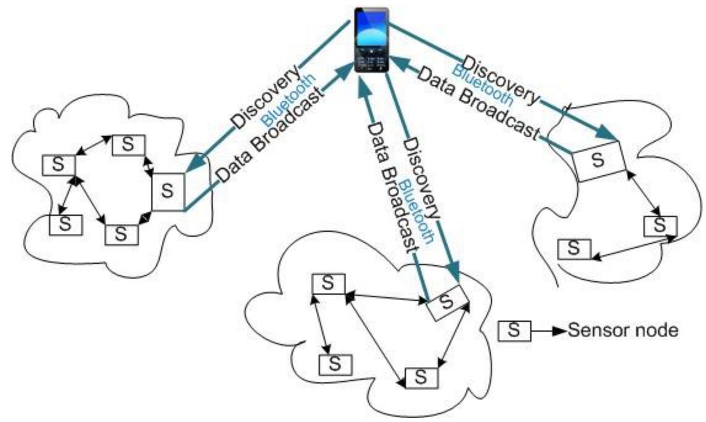

Figure 1. Interacting with diverse WSNs in a physical environment

template mechanism has been embedded on the sensor nodes, by which individual sensor nodes can be described, and sensor data can be interpreted.

IV. Design of a Pervasive Sensor Browser

The sensor browser is designed in anticipation of smart environments comprising of sensor networks with heterogeneous sensing modalities becoming increasingly commonplace over time. This browser is developed to enable pervasive sensing where instances of sensor nodes in the users' immediate surroundings can be discovered and connections established. It seeks to enable dynamic ad-hoc interaction with individual sensor nodes in a peer-to-peer fashion from a mobile device, in the assumption that no open internet connection is available to the sensor platform. Figure 1 illustrates a usage scenario of the sensor browser, where the mobile phone is capable of discovering sensor nodes and interacting with them, according to individual user's specification.

Sensor discovery and data transmission are implemented via Bluetooth. Sensor data is gathered, encoded and transmitted to the identified mobile device in an XML style, which facilitates data perception and interpretation. An adaptive personalized mechanism has also been designed where users' preferences for interested environmental modalities can be considered.

V. Realisation of the Sensor Browser

A. Hardware Platform

The sensor browser has been implemented on a Nokia N95 mobile phone, but can be installed on a wide range of mobile devices that support Java 2 Micro Edition (J2ME). The sensor motes that are deployed in this configuration include a range of programmable sensor boards based on the WASP mote [8] as well as a Shimmer mote [9]. Figure 2 demonstrates a few examples of these sensor boards. Examples include a:

Figure 2. Sensors for pervasive sensing. From clockwise: gas sensor(WASP), GPS sensor (WASP), accelerometer (Shimmer), smartcity (WASP) and event board (WASP)

- gas sensor board with multiple air quality sensors such as CO2, CO, NH3 and so on;
- GPS sensor;
- event sensor board with a presence (PIR) motion sensor, light sensor and so on;
- smart city sensor board with a dust and noise sensor;
- accelerometer hosted on the Shimmer platform.

B. Software Implementation

J2ME is the platform of choice for the sensor browser. A number of Java Specification Requests (JSRs) including those for Bluetooth and mobile 3D graphics have been harnessed. From a software engineering perspective, the intelligent agent paradigm has been adopted as this enables the encapsulation of certain functionality as embedded agents, while supporting collaboration between each of the distinct agents to deliver the final browser experience. The platform is implemented using Agent Factory Micro Edition (AFME) [10], which enables lightweight agents for resource limited devices, such as mobile phones and certain sensor node platforms.

C. The User Experience

For the browser interface, a widget comprising a revolving 3D cube is tailored to facilitate information visualization. Obtained sensor data is illustrated on each surface of the cube, and is usually drawn as a graph that can demonstrate and highlight any trends in the sensed data. Since users may be interested in more than one sensed modality, maybe noise and CO2 levels for example, any combination can be shown on the cube with each face showing one particular modality. In this way, adaptivity and personalization are supported. Figure 4 shows an example of dust trend on the a cube face.

In addition, the cube can be manipulated in a variety of ways. For example, the user can simply press the Fire Key

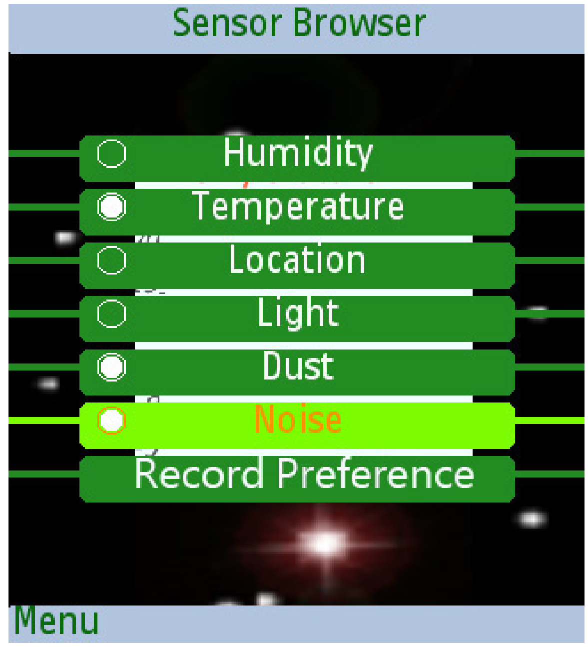

Figure 3. Configuring the Sensor Browser according to individual user requirements

to rotate the cube along X axis. It also can be manually rotated by pressing the navigation keys to rotate along X, Y, and Z axes. Considering the difference sizes of mobile phone screen, the cube may be automatically hosted in the central part of the physical screen, usually occupying two thirds of the screen real estate. Furthermore, users can also zoom in and out of the cube, by clicking the Menu item, where the size of the cube can be configured.

Harnessing the embedded agent mechanism, an adaptive interactive experience is realised, which compromised the following aspects:

- Users can specify those sensing modalities of interest to them with multiple selections from a generic choice of attributes; moreover, the order of their preference can be simply recorded by noting the order of their clicks on the individual attributes. Figure 3 demonstrates a sample snapshot of the typical attributes that might be available.
- Sensor data is visualized in a dynamic and adaptive fashion in response to changes in the sensed data and the user's needs. For example, when one of the user-specified attributes such as noise level changes rapidly, the noise face of the cube may be made appear more frequently during the rotation.
- Personalized alarm mechanism: For each attribute, users may specify certain thresholds. Certain alarms will be raised when the threshold is exceeded. For instance, when the noise level exceeds a threshold that may be harmful to human health, certain alarms can be

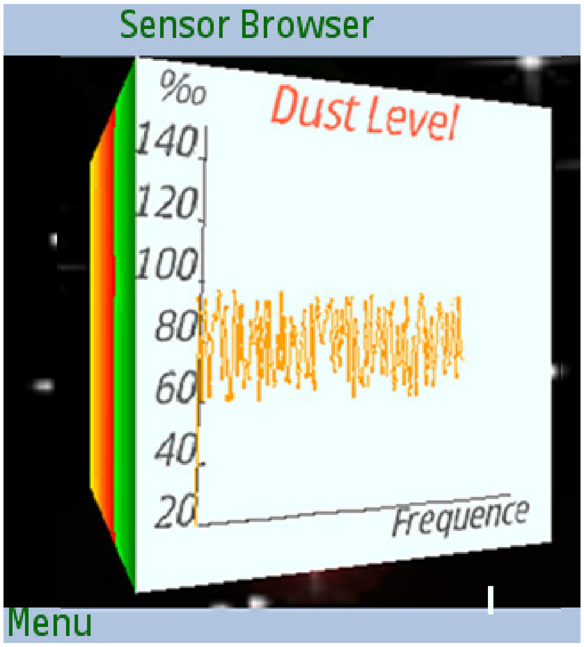

Figure 4. One face of the sensor browser showing the dust levels.

triggered, such as sending a text message to the user, or vibrating the phone.

VI. Ongoing Work

Three concurrent streams of research are continuing. In the first instance, the issue of personalization and adaptivity is being explored, thus enabling the browser act as an Intelligent User Interface (IUI) to the sensor web. Secondly, the current implementation is not a generic solution in the manner originally envisaged or indeed required. Thus, harnessing and customizing a pre-existing middleware solution as a basic framework for universal sensor access, for example, the ITA Sensor Fabric [11] or SIXTH [12], is under investigation. Finally, SensorML, though comprehensive in nature, is not agile enough for pervasive sensing. A lightweight derivative, possibly MoteML, is being considered. This lack of a tractable sensor discovery and description protocol represents a major hurdle in the quest for seamless heterogeneous sensor discovery and interaction in mote-type sensor platforms.

VII. Conclusion

To fully exploit smart environments, a transparent and standardized access approach to embedded sensors is required. In this paper, one approach to realizing a singular framework for pervasive sensor network access has been proposed.

Acknowledgment

This work is supported by Science Foundation Ireland under grant 07/CE/I1147.

References

[1] M. Turon, “Mote-view: A sensor network monitoring and management tool,” *The Second IEEE Workshop on Embedded Networked Sensors (EmNetS-II)*, pp. 11–18, May 2005.

[2] M. Ringwald, M. Yücel, and K. Römer, “Demo abstract: Interactive in-field inspection of wsns,” in *Adjunct Proceedings of the 3rd European Workshop on Wireless Sensor Networks (EWSN 2006)*, Zurich, Switzerland, Feb. 2006.

[3] S. Siorpaes, G. Broll, M. Paolucci, E. Rukzio, J. Hamard, M. Wagner, A. Schmidt, and D. Eurolabs, “Mobile interaction with the internet of things,” in *In Adjunct Proc. of Pervasive 2006 Late Breaking Results*, 2006.

[4] C. Heipke, “Crowdsourcing geospatial data,” *ISPRS Journal of Photogrammetry and Remote Sensing*, pp. 550–557, June 2010.

[5] F. Alt, A. S. Shirazi, A. Schmidt, U. Kramer, and Z. Nawaz, “Location-based crowdsourcing: extending crowdsourcing to the real world,” in *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries*, ser. NordiCHI ’10. New York, NY, USA: ACM, 2010, pp. 13–22.

[6] M. Botts, “Opengis sensor model language (sensor ml) implementation specification,” *Open Geospatial Consortium Inc.*, Oct. 2005.

[7] F. Ali, Y. Feaster, S. K. Wahba, and J. O. Hallstrom, “A metadata encoding for memory-constrained devices,” in *Proceedings of the 49th ACM Southeast Conference (ACM-SE ’11)*. New York, NY, USA: ACM, 2011.

[8] Libelium. Libelium wireless distributed communications. [Online]. Available: http://www.libelium.com/

[9] A. Burns, B. Greene, M. McGrath, T. O’Shea, B. Kuris, S. Ayer, F. Stroiescu, and V. Cionca, “Shimmer - a wireless sensor platform for noninvasive biomedical research,” *IEEE Sensors Journal*, vol. 10, no. 9, pp. 1527 –1534, sept. 2010.

[10] C. Muldoon, G. M. P. O’Hare, R. W. Collier, and M. J. O’Grady, “Towards pervasive intelligence: Reflections on the evolution of the agent factory framework,” in *Multi-Agent Programming:*, A. El Fallah Seghrouchni, J. Dix, M. Dastani, and R. H. Bordini, Eds. Springer US, 2009, pp. 187–212.

[11] J. Wright, C. Gibson, F. Bergamaschi, K. Marcus, R. Pressley, G. Verma, and G. Whipps, “A dynamic infrastructure for interconnecting disparate isr/istar assets (the ita sensor fabric),” in *12th International Conference on Information Fusion (FUSION ’09).*, July 2009, pp. 1393 –1400.

[12] M. J. O’Grady, J. Ye, G. M. P. O’Hare, S. Dobson, R. Tynan, R. Collier, and C. Muldoon, “A middleware for implicit interaction,” in *Computing with instinct*, Y. Cai, Ed. Berlin, Heidelberg: Springer-Verlag, 2011, pp. 143–161.