BROWSING THE SENSOR WEB
Pervasive Access for Wide-area Wireless Sensor Networks

Jie Wan[1], Michael J. O'Grady[1], Gregory M. P. O'Hare[1] and Todor Colakov[2]
[1] *CLARITY: Centre for Sensor Web Technologies, School of Computer Science and Informatics, University College Dublin Dublin, Ireland*
[2] *University of West Bohemia, Pilsen, Czech Republic*

Keywords: Sensor Web, Human Computer Interaction, Pervasive Computing.

Abstract: Wireless Sensor Networks (WSNs) are almost exclusively regarded as data gathering entities. Various sensed data elements are captured and routed back to a central server for processing, visualization and interpretation. However, it can be realistically conjectured that scenarios will increasingly emerge that demand a facility for ad-hoc interaction with individual sensor nodes. Moreover, such interaction will occur in the physical environment in close proximity to where the sensor node is physically located. In this paper, the need for in-situ ad-hoc interaction is motivated. A methodology for facilitating such interaction is presented, and the implementation of a sensor browser is described.

1 INTRODUCTION

Pervasive Computing envisages a world of embedded artifacts connected by pervasive networking technologies. Moreover, seamless and intuitive interaction is perceived as a key characteristic of such systems. While Wireless Sensor Networks (WSNs) are a fundamental enabling technology for pervasive computing, and have been harnessed in a diverse range of applications for example, surveillance and environmental monitoring, access to such networks is inherently centralized, and support for point-to-point adhoc interaction with individual sensor nodes is lacking. Cases where such interaction would be desirable might include law enforcement where, after an incident, officials at the scene could obtain instant access to security cameras within their immediate vicinity. Crowd-sourcing activities are another avenue where such access would be useful. For the purposes of this discussion, the practical issue of network maintenance in the field is considered.

Section 2 outlines some documented approaches to interaction with WSNs. In Section 3, the need for ad-hoc interaction with WSNs is motivated through a practical example in network Operation and Maintenance (O&M). A methodology for enabling ad-hoc interaction is described in Section 4. A prototype sensor browser is outlined in Section 5 after which the paper is concluded.

2 RELATED RESEARCH

Interaction and visualization in WSN contexts are receiving increasing attention by the research community. Initially, there is a focus on WSN management issues, and a number of frameworks have been described in this area. Examples include SNMS (Tolle and Culler, 2005), TASK (Buonadonna et al., 2005), Mote-View (Turon, 2005), SensibleDoctor (Cha et al., 2008), Wireless Sensor Network Remote Interaction Tool (Tirkawi and Fischer, 2008) and Octopus (Jurdak et al., 2008). Another approach describes how Geographic Information Systems (GIS) and web technologies may be integrated to enable online visualization (Fan and Biagioni, 2004). However in all these cases, the predominant model is one of centralized access and control.

Other researchers have considered issues relating to WSN access while in the physical WSN environment. SensAR is an innovative approach that harnesses Augmented Reality (AR) for the visualization of real-time environmental data using a handheld computer (Goldsmith et al., 2008). Likewise, the speckled computing consortium harness AR as an interaction paradigm for micro-sensor networks (Leach and Benyon, 2006). Gauger et al explore different physical modalities for interaction with individual nodes, including gesture and light (Gauger et al., 2009). Tricorder (Lifton et al., 2007) is a dedicated device for browsing and navigating WSNs. It can query local sensor nodes directly or remote sensor no-

Wan J., J. O'Grady M., M. P. O'Hare G. and Colakov T..
BROWSING THE SENSOR WEB - Pervasive Access for Wide-area Wireless Sensor Networks.
DOI: 10.5220/0003809601090112
In *Proceedings of the 1st International Conference on Sensor Networks* (SENSORNETS-2012), pages 109-112
ISBN: 978-989-8565-01-3

Figure 1: Topology of a *ideal* sensor field.

Figure 2: Topology of a *realistic* sensor field.

des by issuing a multi-hop request. Using an embedded compass for orientation, and a signal strength indicator for position, it can be used in a point-and-browse fashion while physically in the WSN. Tricorder is designed to operate with the Plug sensor network. Such a network has potential in domestic or occupational environments; however, it is not suitable for wide area sensor networks of the kind used for environmental monitoring. Ringwald et al (Ringwald et al., 2006) have developed a tool for interactively inspecting WSNs in the field. It allows querying of individual nodes and firmware upgrades on the nodes as well as topology viewing. Extensive use is made of Bluetooth, even at sensor level.

The Sensor Browser described in this paper complements and builds upon these approaches, but is more generic in its applicability in that it seeks to operate on a range of popular smart phones, and support a variety of sensor platforms.

3 CASE STUDY: OPERATIONS & MAINTENANCE

The primary function of a sensor is to measure either individual or multiple phenomena, and to report this measurement to a dedicated sensor or base station. This leads to the second key function: the routing of data. Sensors may also serve as routers, routing data from other sensors to the base station, or more likely, to other sensors that are closer to the base station. A failure in either of these functions would compromise the operation of the WSN, requiring physical intervention in the field to correct the problem.

Figure 1 illustrates what an uniform WSN topology might be expected to look like. Sensors are laid out in the coverage area in a grid-like fashion, all equidistant such that the entire area is covered from a sensing and routing perspective. Each sensor has a number of paths for routing data to the base station,

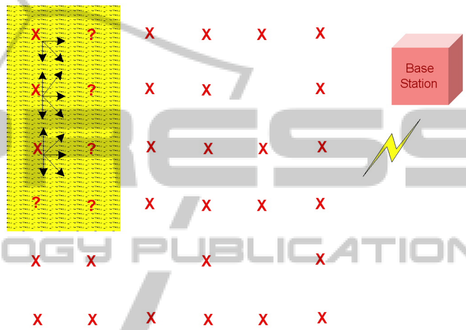

Figure 3: Topology of a *faulty* sensor field.

which in turn can either process it in situ or pass it further up the network stack for further analysis.

Over time, a WSN will deteriorate, resulting in a number of sensors no longer functioning (Figure 2). However, the WSN itself is still functioning; data can still be routed to the base station, and the gaps in the sensing function may be estimated using various modeling techniques.

A major problem arises when a combination of sensors fail such that either the sensing or routing function is seriously compromised for part of the WSN coverage area. Figure 3 illustrates a case of routing failure where part of the network is isolated and cannot communicate with the base station. To remedy this situation, physical intervention is required - this would frequently demand a capability for in situ ad-hoc interaction with individual nodes.

4 ENABLING AD-HOC INTERACTION

From a hardware perspective, three components are necessary to realize a sensor browsing experience.

- Mobile phone - As the de facto standard for ubiquitous communication, high-end mobile phones

Figure 4: Sensor Browser: introduction screen.

and smart phones increasingly incorporate a suite of technologies that enables them to host specialized third-party and custom-developed applications. In this case, a Nokia N97 was harnessed.

- Sensor platform - a Mica2 unit was adopted as it was considered an archetypical sensor device, capable of sensing a number of common phenomena. For communications it uses RF (868/916 MHz).
- Protocol Convertor - mobile phones and sensor platforms use different communications technologies so it is necessary to enable a protocol convertor through hardware. A base station was constructed using a second Mica2 mote mounted on a PC Interface board. This was then augmented with a BlueSnapXP Mobile Bluetooth RS-232 dongle from Serialio.com. This supports the standard Bluetooth Serial Port profile.

All motes were programmed using NesC. The browser itself on the mobile phone was developed in Java ME.

5 THE SENSOR BROWSER

Figure 4 illustrates the introduction screen of the Sensor Browser. This enables access to various functionality supported by the browser. In practice, a sensor may support a multitude of sensed modalities, for example, temperature, humidity, ambient noise levels

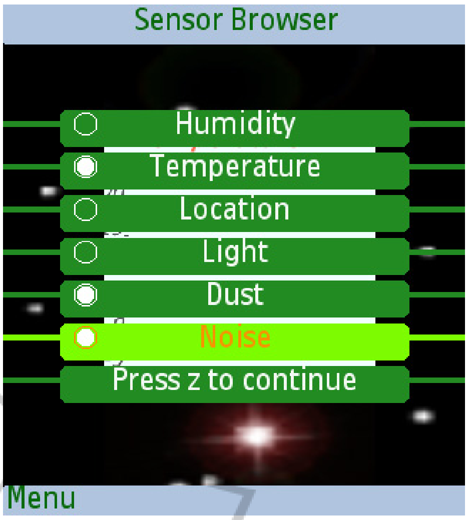

Figure 5: Sensor Browser: identifying the temperature, dust and noise as the sensed values of interest.

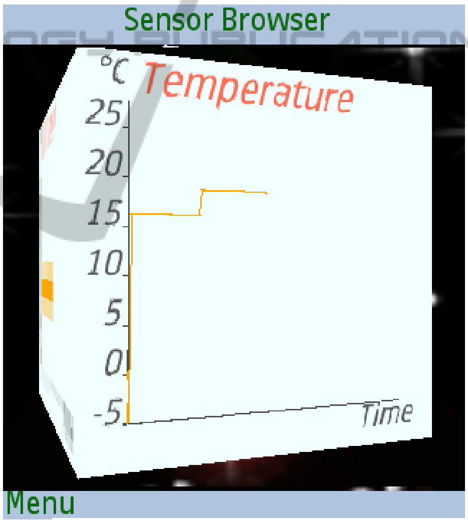

Figure 6: Sensor Browser: trends are plotted on the individual faces of a rotating cube for the sensed phenomena under investigation.

and so on. But users may only be interested in some of these, depending on their need. Thus, they can specify multiple modalities that are interesting to them, for example, temperature, dust and noise (Figure 5), and visualize the sensed data via the browser. A number of other modalities such as the battery level, air pollution level can also be monitored while might not be of interest for general users, additional data about the network topology, link quality can be gathered if it is available.

A key feature of the browser is that it continuously records the required sensed values as they are encountered. In this way trends can be visualised. The sensor adopts a cube metaphor, showing the trends for each required sensed parameter on an individual face (Figure 6).

6 FUTURE WORK

A number of improvements are planned for this initial prototype. Managing scalability and sensor heterogeneity are essential, thus the possibility of standardizing on SensorML or MoteML (Ali et al., 2011) is being explored. This would also form the basis for a more robust approach to configuration and debugging. Augmenting the user interface using GPS and GoogleMaps would enable a realistic visualization of the spatial relationship between the sensors. Finally, until Zigbee and associated technologies are integrated into mobile phones, it will be necessary to support a protocol convertor. Mobile base stations of the type described in (Angove et al., 2011) offer alternatives approaches in this instance.

7 CONCLUSIONS

This paper has presented an initial prototype of a mobile sensor browser; in contrast with previous approaches, this browser implements a number of novel features. The adoption of the dynamic cube metaphor enables an intuitive tool for users to view various sensed parameters. Furthermore, an adaptive personalization mechanism has been harnessed; with the consideration of individual user's profile, user preferences and physical environments attributes, select sensor data can be gathered and visualized in a user-specified manner. In addition, real-time sensing, data collection and visualization have been implemented, as well as short term historical data recording for trend analysis.

ACKNOWLEDGEMENTS

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

REFERENCES

Ali, F., Feaster, Y., Wahba, S. K., and Hallstrom, J. O. (2011). A metadata encoding for memory-constrained devices. In *Proceedings of the 49th Annual Southeast Regional Conference*, ACM-SE '11, pages 191–196, New York, NY, USA. ACM.

Angove, P., O'Grady, M. J., Hayes, J., O'Flynn, B., O'Hare, G. M. P., and Diamond, D. (2011). A mobile gateway for remote interaction with wireless sensor networks. *Sensors Journal, IEEE*, 11(12):3309 –3310.

Buonadonna, P., Gay, D., Hellerstein, J., Hong, W., and Madden, S. (2005). Task: sensor network in a box. *Wireless Sensor Networks, 2005. Proceeedings of the Second European Workshop on*, pages 133–144.

Cha, S., Shin, H., and Cha, H. (2008). Sensible doctor - a mobile diagnosis tool for wireless sensor networks. *Information Processing in Sensor Networks, 2008. IPSN '08. International Conference on*, pages 565–566.

Fan, F. and Biagioni, E. S. (2004). An approach to data visualization and interpretation for sensor networks. In *Proceedings of the Proceedings of the 37th Annual Hawaii International Conference on System Sciences (HICSS'04) - Track 3 - Volume 3*, HICSS '04, Washington, DC, USA. IEEE Computer Society.

Gauger, M., Saukh, O., and Marron, P. J. (2009). Talk to me! on interacting with wireless sensor nodes. In *PERCOM '09: Proceedings of the 2009 IEEE International Conference on Pervasive Computing and Communications*, pages 1–8, Washington, DC, USA. IEEE Computer Society.

Goldsmith, D., Liarokapis, F., Malone, G., and Kemp, J. (2008). Augmented reality environmental monitoring using wireless sensor networks. *iv*, 0:539–544.

Jurdak, R., Ruzzelli, A. G., O'Hare, G. M. P., and Lopes, C. V. (2008). Octopus: A dashboard for sensor networks visual control. *The 14th Annual International Conference on Mobile Computing and Networking, Mobicom08 (Demo)*.

Leach, M. and Benyon, D. (2006). Interacting with a speckled world. In *ADPUC '06: Proceedings of the 1st international workshop on Advanced data processing in ubiquitous computing (ADPUC 2006)*, page 3, New York, NY, USA. ACM.

Lifton, J., Mittal, M., Lapinski, M., and Paradiso, J. A. (2007). Tricorder: A mobile sensor network browser. In *Proceedings of the ACM CHI 2007 Conference - Mobile Spatial Interaction Workshop*.

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

Tirkawi, F. and Fischer, S. (2008). Remote interaction tool for wireless sensor networks. *Wireless Pervasive Computing, 2008. ISWPC 2008. 3rd International Symposium on*, pages 360–364.

Tolle, G. and Culler, D. (2005). Design of an application-cooperative management system for wireless sensor networks. *Wireless Sensor Networks, 2005. Proceeedings of the Second European Workshop on*, pages 121–132.

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