

Towards Design of Context-Aware Sensor Grid Framework for Agriculture

Aqeel-ur-Rehman, and Zubair A. Shaikh

Abstract—This paper is to present context-aware sensor grid framework for agriculture and its design challenges. Use of sensor networks in the domain of agriculture is not new. However, due to the unavailability of any common framework, solutions that are developed in this domain are location, environment and problem dependent. Keeping the need of common framework for agriculture, Context-Aware Sensor Grid Framework is proposed. It will be helpful in developing solutions for majority of the problems related to irrigation, pesticides spray, use of fertilizers, regular monitoring of plot and yield etc. due to the capability of adjusting according to location and environment. The proposed framework is composed of three layer architecture including context-aware application layer, grid middleware layer and sensor network layer.

Keywords—Agriculture, Context-Awareness, Grid Computing, and Sensor Grid.

I. INTRODUCTION

AGRICULTURE is one of the most important areas on which human life is very much dependent. There is a need of use of different technologies to support this domain to have low cost and appropriate solutions to many different problems. The proposed framework is combining three well known technological domains namely context-aware computing, grid computing and sensor networks.

The field of context-aware computing has been closely related to the development of intelligent and ubiquitous systems. According to Dey et al. [1]:

“A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user’s task”.

The context-aware computing term was first coined by Schilit and Theimer [2] in 1994. Author describes context-aware applications that

“adapt according to its location of use, the collection of nearby people and objects, as well as the changes to those objects over time”.

Grid computing is an area that has been evolved rapidly and effectively in the discipline of distributed computing. The term Grid computing was introduced in 1996 and formalized

in 1999 [3]. In the last 10 years, definition of Grid undergone through several amendments [4], [5]. Gregor von Laszewski used the term ‘Production Grid’ to define the Grid concept. The Grid is defined [4] as follows:

“A production Grid is a shared computing infrastructure of hardware, software, and knowledge resources that allows the coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organizations to enable sophisticated international scientific and business-oriented collaborations”.

The Grid provides the platform to share resources attached to it (i.e. applications, computing power, memory, data storage facilities etc.) across multiple organizations and administrative domains. After the introduction of Open Grid Service Architecture (OGSA) [6], concept of service oriented grid is evolved that is to provide a shared pool of resources in such a way that any node can get the resource as service on demand as the resource is directly attached to it.

Sensor network is another evolving area. Sensor network is a collection of small units (sensor nodes or motes) in distributed fashion. Sensor nodes or ‘motes’ are small devices that can sense the physical world. They have small battery power, wireless transceiver and a processing unit. Sensors network is defined by Thomas Haenselmann [7] as follows:

“A sensor network is a set of small autonomous systems, called sensor nodes which cooperate to solve at least one common application. Their tasks include some kind of perception of physical parameters.”

Military, health, agriculture, home etc. are the major application areas of sensor networks. Different application areas possess different technical problems that researchers are currently resolving.

The combination or merger of sensor networks with the wired grid is termed as Sensor Grid. It is also termed as ‘Pervasive Grid’ by different researchers [8]–[12]. The combination of these two technologies provides low cost high performance computing to physical world data perceived through sensors.

Sensor networks are being used in the area of agriculture very effectively. Due to the different weather, soil, water and land conditions, diverse methods of analysis and solutions have been proposed by researchers that are fixed for specific problem(s), land and weather conditions. That instigates need of a common framework specifically for agriculture that can

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be helpful in developing solution for irrigation control, pesticides spraying, plot and yield monitoring, soil examining, cattle farming etc. under diverse conditions. Designing of Context-Aware Sensor Grid framework for Agriculture is an effort in this regard.

The rest of this paper is organized as follows. Section 2 provides framework details and its design challenges. Section 3 discusses about related work in the area of agriculture. Finally, we offer our conclusions in section 4.

II. CONTEXT-AWARE SENSOR GRID FRAMEWORK FOR AGRICULTURE

Context-Aware Sensor Grid is a combination of three promising technological domains that are context-aware computing, grid computing and sensor networks. In very simple words Context-Aware Sensor Grid can be defined as follows:

“The Context-aware Sensor Grid is a distributed computing environment that has shareable resources having the power to sense the physical world with the capability of high computing power on low price. It is adjustable to the environment autonomously on the basis of collected information.”

The architecture of the sensor grid can be seen in Figure 1. Our proposed Context-aware sensor grid framework [13] for agriculture is adaptable to different conditions of weather, land, and water. In addition, it also has the provision to deal with different problems and variety of crops. The framework comprises on three layers namely context-aware application layer, grid middleware layer and sensor network layer.

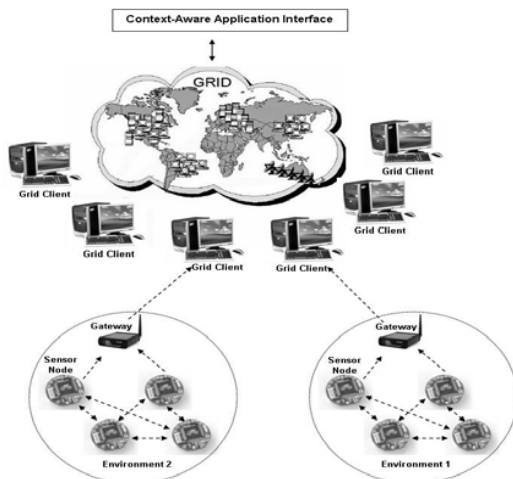


Fig. 1 Context-Aware Sensor Grid Architecture

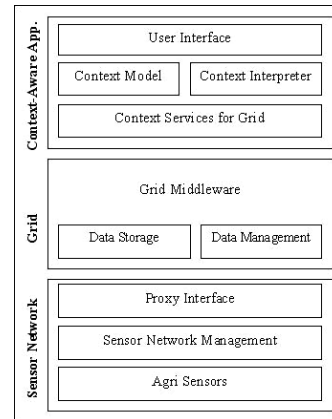


Fig. 2 Context-Aware Sensor Grid Framework for Agriculture

Context-aware application layer is to foster different conditions related to soil and yield as well as to deal with different diverse problems related to agriculture. Grid middleware layer is to get benefit of low cost high performance computing as well as to have cheap but massive data store. Sensor network layer is to gather information about the available current conditions of the land and harvest.

III. BUILDING BLOCKS OF THE FRAMEWORK

Major building blocks of the framework are:

A. Context Model

Context model block is to deal with the context acquisition, definition and storage.

B. Context Interpreter

This block is to provide service to the administrator in interpreting context values as primitive input.

C. Context Services to Grid

To make the grid context enabled, there is a need of grid services that are not available in OGSA. This block is to cater such services.

D. Data Storage and Management

This block is to deal with data services for storage and management. Due to the heterogeneous and quantity of sensors, variety of data in bulk will be collected. There will be need of data classification, clustering, aggregation and fusion. This block will help for such issues.

E. Proxy Interface

Connectivity of sensor network with grid requires an interface that can provide facility to convert data format in grid compatible form. Proxy interface block is to provide such facility.

F. Sensor Network Management

Sensor network management is an important task as sensor network is highly dynamic in nature. This block is to deal with

sensor communication, topology, power management etc.

G. Agri-Sensors

Agriculture domain requires monitoring of soil condition, weather, water-flow, crop etc. For that purpose different sensors are needed. Agri-Sensors block is to deal agriculture related sensors and their requirements.

IV. CHALLENGES IN DESIGNING CONTEXT-AWARE SENSOR GRID FRAMEWORK FOR AGRICULTURE

There are several challenges in the design of context-aware sensor grid framework that require special consideration.

A. Context Model

Ontology based context modeling is a popular approach. The important rationales in designing context ontology [14] include simplicity, flexibility, extensibility, generality and expressiveness. In case of agriculture, context can be seen from two points of view. One is the sensed data values that can be used with location and time values to extract the current context or situation of the land, water, crop etc. while second is the context as implicit inputs that can be defined for different land conditions, crops types, weather etc. In the proposed framework there is a need of combining both types of context values. Main challenge in this regard is to develop a flexible and extensible ontology that can define several different location conditions and crops requirements.

B. Grid Services for Context-Awareness

Applications that are developed for grid uses grid services. Open Grid Service Architecture (OGSA) that is defined by Global Grid Forum (GGF) presents several services to use grid as service oriented grid. But unfortunately OGSA does not provide the support for context-aware services till now. In 1994, Kerry Jean et. al. [15] presented some extensions for context-aware OGSA based grid services. The challenge of defining such services is partially solved but more work is needed in this regard.

C. Data Management and Storage

Data clustering, classification, aggregation, fusion are very important and critical functions of sensors data management. In agriculture scenario variety of sensors with different connectivity approaches are used. In Context-aware scenario, there is a need of a technique that can address context-sensing challenges. Huadong Wu work [16] in this regard is a good contribution. Such solutions are needed that can be implemented in grid environment.

D. Sensor Network Connectivity with Grid

Different approaches have already been provided to connect sensor network with grid that include middleware approach [10], [17], proxy based approach [11], agent-oriented runtime approach [8], overlay network approach [10], [18] etc. The problems with majority of available solutions are either they are proprietary or they support fixed kind of sensor topology. There is a need of open source solution that can handle variety

of sensor grid architectures.

V. RELATED WORK

Sensor network based solutions are in use of agriculture community for several years. They are using it for monitoring and controlling purposes. Following are some of the sensor network projects that have been developed specifically for agriculture domain.

W. Zhang et. al. at Carnegie Mellon University [19] developed a small wireless sensor network to monitor plant nursery. Sensors were used to collect soil and air humidity, moisture, temperature and light information.

Irrigation control is one of the important areas in agriculture. Several sensor based projects have been developed [20], [21] specifically for controlling irrigation water keeping its importance for increasing yields. Tapankumar et. al. [20] designed and developed a computer based drip irrigation control system having the facility of remote data acquisition. While Yunseop Kim et. al. [21] developed an electronically controlled sensor based irrigation system that provides the facility to monitor soil moisture and temperature, weather information and sprinkler position remotely using the Bluetooth and GPS technologies.

Fungus and pests are major problems in agriculture. Sensor networks also been used to overcome these problems. Aline Baggio at Delft University of Technology [22] developed a project to deal the potato crop disease. Sensors were used to sense humidity and temperature. Monitoring of these two facts helped them to reduce the disease.

Cattle's farming is also closely related to the agriculture domain. Green pastures are used by cattle for grazing. Tim Wark and his other team members [23] at CSIRO ICT center, Australia created a pervasive, self configurable sensor based solution to analyze the behavior of animals and their control as well as the pastures assessment. Grass growth was analyzed through photographic sensors so that animals can be moved towards green pastures. They also used specially designed sensor to monitor animal behavior like sleeping, grazing, ruminating etc.

VI. CONCLUSION

Need of common framework for agriculture domain instigated us to develop context-aware sensor grid framework for agriculture. This framework has the capability to deal with different problems like irrigation control, pesticides spraying, soil and land monitoring, weather monitoring etc. Context-awareness capability along with the grid computing facility makes it highly dynamic and low cost solution that can be used for diverse conditions and locations. Several challenges are pointed out that need profound consideration to make this proposed framework a reality.

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REFERENCES

- [1] A. K. Dey, and G. Abowd, "Towards a Better Understanding of Context and Context-Awareness," presented at the Workshop on The What, Who, Where, When, and How of Context-Awareness, as part of the 2000 Conference on Human Factors in Computing Systems (CHI 2000), The Hague, The Netherlands, April 3, 2000.
- [2] B. N. Schilit, and M. M. Theimer, "Disseminating active map information to mobile hosts," *IEEE Networks*, 8(5), pp. 22–32, 1994.
- [3] I. Foster and C. Kesselman, *The Grid: Blueprint for a New Computing Infrastructure*, Morgan Kaufmann Publishers, 1st Edition 1999, 2nd Edition, 2003.
- [4] Gregor von Laszewski, "The Grid-Idea and Its Evolution," *it - Information Technology*, Volume: 47, Issue: 6, pp. 319–329, Oldenbourg Wissenschaftsverlag GmbH, Germany, 2005.
- [5] Ian Foster, "What is the GRID? A three point checklist," *GRID today*, July 2002.
- [6] I. Foster, C. Kesselman, J. Nick, and S. Tuecke, "The Physiology of the Grid: An Open Grid Services Architecture for Distributed Systems Integration," *Globus Project*, 2002.
Available: www.globus.org/research/papers/ogsa.pdf
- [7] Thomas Haenselmann, *An FDL'ed Textbook on Sensor Networks*, April 2006.
Available: http://www.informatik.uni-mannheim.de/~haensel/sn_book/
- [8] Vipul Hingne, Anupam Joshi, Tim Finin, Hillol Kargupta, Elias Houstis, "Towards a Pervasive Grid," *ipdps*, p. 207b, International Parallel and Distributed Processing Symposium (IPDPS'03), 2003.
- [9] Manish Parashar, Jean-Marc Pierson, "When the Grid becomes pervasive: A vision on Pervasive Grids," presented at the Hellenic European Conference on Computer Mathematics & its Applications (HERCMA 2007), Athens, Greece, September 2007.
- [10] G. Coulson, "Pervasive Grids: Integrating Sensor Networks into the Fixed Grid," invited paper, in *Proc. Euro-American Workshop on Middleware for Sensor Networks*, International Conference on Distributed Computing in Sensor Systems (DCOSS '06), San Francisco, USA, June 18–20, 2006.
- [11] Hock Beng Lim, Yong Meng Teo, Protik Mukherjee, Vinh The Lam, Weng Fai Wong, Simon See, "Sensor Grid: Integration of Wireless Sensor Networks and the Grid," in *Proc. the IEEE Conference on Local Computer Networks 30th Anniversary (LCN'05)*, 2005, pp. 91–99.
- [12] C. Tham and R. Buyya, "SensorGrid: Integrating Sensor Networks and Grid Computing," *CSI Communications, Special Issue on Grid Computing*, Computer Society of India, July 2005.
- [13] Aqeel-ur-Rehman and Zubair A. Shaikh, "A Vision of Context-Aware Sensor Grid for Agriculture". unpublished.
- [14] Panu Korpipää and Jani Mäntyjärvi, "An Ontology for Mobile Device Sensor-Based Context Awareness," in *Proc. Context '03*, LNAI no. 2680, 2003.
- [15] Kerry Jean, Alvin Tan and Alex Galis, "Context-Aware GRID Services: Issues and Approaches," *University College London, Electrical Engineering Department, Torrington Place, London*, 2004.
- [16] Huadong Wu, "Sensor Data Fusion for Context-Aware Computing Using Dempster-Shafer Theory," *Ph.D. dissertation*, Carnegie Mellon University, Pittsburgh, Pennsylvania, December 2003.
- [17] Mark Gaynor, Steven L. Moulton, Matt Welsh, Ed LaCombe, Austin Rowan, John Wynne, "Integrating Wireless Sensor Networks with the Grid," *IEEE Internet Computing*, vol. 08, no. 4, pp. 32–39, Jul/Aug 2004.
- [18] P. Grace, G. Coulson, G. S. Blair, B. Porter, "Deep Middleware for the Divergent Grid," in *Proc. IFIP/ACM/USENIX Middleware 2005*, France, Nov 2005.
- [19] W. Zhang, G. Kantor, and S. Singh, "Integrated Wireless Sensor/Actuator Networks in an Agricultural Application," in *Proc. 2nd ACM Int'l Conf. Embedded Networked Sensor Systems (SENSYS 04)*, ACM Press, 2004, pp. 317.
- [20] Tapankumar Basu, Vijaya R. Thool, Ravindra C. Thool, and Anjali C. Birajdar, "Computer Based Drip Irrigation Control System with Remote Data Acquisition System," in *Proc. 4th World Congress Conf. Computers in Agriculture and Natural Resources*, USA, July 2006.
- [21] Y. Kim, R.G. Evans, and W. Iversen, "Remote Sensing and Control of Irrigation System using a Distributed Wireless Sensor Network," *IEEE Trans. Instrumentation and Measurement*, 2007.
- [22] A. Baggio, "Wireless Sensor Networks in Precision Agriculture," in *Proc. ACM Workshop Real-World Wireless Sensor Networks*, 2005.
- [23] T. Wark, P. Corke, P. Sikka, L. Klingbeil, Y. Guo, C. Crossman, P. Valencia, and D. Swain, "Transforming Agriculture through Pervasive Wireless Sensor Networks," *IEEE Pervasive Computing*, pp. 50–57, April-June 2007.